Opportunity to learn mathematics in low and high performing countries: a cross-national analysis of teachers enacting the curriculum and associated factors

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OPPORTUNITY TO LEARN MATHEMATICS IN LOW AND HIGH PERFORMING COUNTRIES: A CROSS-NATIONAL ANALYSIS OF TEACHERS ENACTING THE CURRICULUM AND ASSOCIATED FACTORS

by

Treisy Romero-Celis

A Dissertation
Submitted to the University at Albany, State University of New York
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Doctor of Philosophy

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DEDICATION

A Pedro y Valeria, mi inspiración.
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Abstract

This exploratory study compares the opportunities to learn mathematics intended and enacted between countries with high and low student average performance levels, according to the Trends in International Mathematics and Science Study (TIMSS). It analyzes the differences in OTL in relation to some of the factors that influence teachers’ instructional decisions. The analysis contributes to the knowledge about teachers’ role in the enactment of mathematics curricular policy and that of curricular governance.

Taking a quantitative approach, the study uses data from the TIMSS 2011 to explore and compare the OTL, intended and enacted by teachers, as well as the gap between these two dimensions, in ten low and eight high performing countries. Policy instruments and teacher characteristics, in addition to their association with OTL mathematics, are also examined and compared between these two groups of countries.

Descriptive analysis of OTL mathematics depicts relevant differences, but also considerable similarities in intended and enacted OTL of low and high performers. This finding and the important gaps between the two curricular dimensions identified in both groups of countries challenge the notion of the existence of a high achieving mathematics curriculum.

Based on inferential statistics, results indicate differences between and across low and high performers in the associations of policy instruments and teacher factors with OTL, providing evidence in support of the claim that actors and local context redefine policies taken from other systems. Finally, this study argues that the divergence between intentions and enactment of the mathematics curriculum can also be regarded as teachers’ agency and re-defining of curricular policy in ways that are responsive to student needs.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>PE</td>
<td>Performance expectations</td>
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<tr>
<td>HCIS</td>
<td>Highly challenging instructional strategies</td>
</tr>
<tr>
<td>HP</td>
<td>High performing countries or territories</td>
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<td>HDPE</td>
<td>High demanding performance expectations</td>
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<tr>
<td>IEA</td>
<td>International Association for the Evaluation of Educational Achievement</td>
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<tr>
<td>IS</td>
<td>Instructional strategies</td>
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<td>IT</td>
<td>Instructional time</td>
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<td>LCIS</td>
<td>Low challenging instructional strategies</td>
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<td>LDPE</td>
<td>Low demanding performance expectations</td>
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<td>LP</td>
<td>Low performing countries or territories</td>
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<tr>
<td>LLECE</td>
<td>Laboratorio Latinoamericano de Evaluación de la Calidad de la Educación</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
</tr>
<tr>
<td>OTL</td>
<td>Opportunity to learn</td>
</tr>
<tr>
<td>PD</td>
<td>Professional development</td>
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<tr>
<td>PIRLS</td>
<td>Progress in International Reading Literacy Study</td>
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<tr>
<td>PISA</td>
<td>Program for International Student Assessment</td>
</tr>
<tr>
<td>TERCE</td>
<td>Tercer Estudio Regional Comparativo y Explicativo</td>
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<tr>
<td>TIMSS</td>
<td>Trends in International Mathematics and Science Study</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
</tr>
<tr>
<td>UNICEF</td>
<td>United Nations International Children's Emergency Fund</td>
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Chapter 1. INTRODUCTION

1.1. Statement of the problem

Teachers’ enacting of the curriculum represents the opportunities made available to students to attain the knowledge, skills, key attitudes and values considered necessary to become engaged and prosperous citizens of society. Although there is often disagreement among actors in society as to what the content and goals of the curriculum should be, once these have been established, education systems direct all efforts towards achieving them. The quality of education systems is often measured in terms of the degree to which these goals are being achieved. Thus, providing teachers with the capacity and the resources to enact the curriculum as intended is of uttermost importance in education systems. Education reform, and particularly curriculum reform, in many countries has sought to achieve this.

However, in most societies there is very little information on the opportunities to learn (OTL) that teachers provide in their classrooms, and how these reflect intended curriculum policy. Significantly, the research on curriculum enactment suggests that, in many cases, the alignment between intended curriculum policy and the enactment of that policy in classrooms, is at best poorly understood, and at worst, extremely problematic.

Curricular intentions embody the purpose and the goals of an education system. They are shaped by societal ideologies about the kind of individuals that it aspires to develop and the role of schooling in achieving these aspirations. Curricular intentions establish, sometimes in broad and others in more specific terms, the teaching and learning that should take place inside schools and classrooms, in knowledge, skills, attitudes, and values; and the expectation of policymakers and educational authorities is that teachers follow through with these intentions.
Thus, the divergence between the enacted curriculum, which embodies teachers’ instructional decisions, and the intended curriculum is considered a failure of the system to work towards advancing its purpose, and is, therefore, considered problematic. The issue is highlighted by the significant association found in empirical studies between the OTL given during instruction, which describe the enacted curriculum, and learning gains (Porter and Gamoran 2002; Schmidt et al. 1997; Schmidt and McKnight 2012; Valverde et al. 2002). Recognizing the important role that family and out of school factors have on students’ learning, including the opportunities to learn accessed outside the school, such as private tutoring or shadow education, the opportunities provided by teachers in the classroom matter for learning. And since the probability that students will learn is directly related to that which they are given the opportunity to learn, divergence diminishes the possibilities of attaining established learning goals, and with that, undermines the quality of an education system. In turn, divergence, particularly when it does not respond to situations or specific and legitimate demands from different stakeholders, is often seen as the reflection of ineffective educational institutions and the policies that govern them.

The study of the relationship between the enacted and the intended curriculum in developed and developing countries reveals different kinds of factors as the potential cause for divergence. The lack of clarity or detail in curriculum policy, teachers’ diverging interests from national objectives, textbooks that do not depict curricular policy, teachers’ lack of knowledge and pedagogical skills, assessment policies and the focus of these on particular school subjects, the perceived status of institutional importance of certain school subjects, students’ deficient

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1 OTL and enacted curriculum are used as similar terms in this study: the operationalization of the OTL provided by teachers describes the enactment of the curriculum, and teachers enacting of the curriculum defines the OTL made available to students. However, OTL has been studied not only as a manifestation of the enacted curriculum, but also in relation to the intended curriculum. Thus, a difference between the terms is that enactment clearly involves teachers’ instructional decisions.
prior knowledge, lack of teaching resource, and school demands placed on teachers are some of the causes identified within the education system suggested by researchers (Elmore and Sykes 1992; Datnow 2006; Valverde 2004; Pinar and Irwin 2005). There are also causes that are outside the school and the education system, such as parents and community resources, demands, culture, values and beliefs. Many of these factors are indeed obstacles to enacting a curriculum that is in line with intentions and to better learning. But, should all factors that cause teachers to diverge from the intended curriculum be considered negative elements that somehow, through policy instruments, should be limited in their influence of the enacted curriculum? And is this divergence indeed an obstacle to student learning?

The analyses of policy implementation, and the study of the reasons for divergence between the intended and enacted curriculum, ascertain that teachers’ decisions about the curriculum they teach are partly determined by curricular intentions and strongly influenced by a whole set of factors. In this claim, supported in this study, researchers recognize teachers’ discretion over instructional decisions and active role in the making of curriculum (Elmore and Sykes 1992; Jackson 1992; Lipsky 1980; Schwab in Clandinin and Connelly 1992).

Undoubtedly, institutional, organizational, contextual, cultural, and individual factors, such as the norms that regulate teachers’ work, the degree of autonomy given to schools, teacher collaboration cultures within schools, and teachers’ own experiences, bring to bear on teachers’ instructional decisions. Insofar as these influencing factors differ from one context to another, divergence between the two levels of the curriculum is bound to occur. Similarly, variation regarding the enactment of the curriculum across contexts, including schools, regions and nations is also to be expected. In developing countries, for example, the scarcity of resources such as textbooks, which are more important in certain school subjects, the lack of adequately prepared
teachers, the use of contract teachers and their high absenteeism from classrooms, or the large class sizes may translate into higher levels of divergence.

Given all these elements, within and outside the education system, the divergence and variation in the enacted curriculum may be inevitable. However, policymakers and education leaders, particularly in developing or poor performing nations, search for the policy instruments and actions that will bring teachers in closer alignment with curricular intentions. Several national reforms in the past few decades, for example, have been geared towards raising curricular standards or establishing accountability and teacher evaluation and supervision policies. Learning about the differences between teachers’ instruction and established curricular policy within particular governance systems across countries that have both low and high achievement is essential to understanding further several aspects of curriculum implementation: first, teachers’ role in defining the curriculum; second, the need for strict correspondence between intentions and enactment; and finally, the kinds of policies or governance structures that can better support teachers given their established role. Accordingly, the analysis of the main factors or policy instruments, specifically teacher education, professional development, supervision, and evaluation policies, in curricular governance systems intended to direct teachers practice is relevant to this study.

Some scholars highlight the complexity of generating change in teaching practice, even with subsequent reform efforts and the emergence of new paradigms in teaching and practices; some sustain that few substantial changes have occurred as a result. Cuban (2013), for example, notes that the numerous reforms of the last century in the United States have produced some change in classroom practice, blending new content, technologies and approaches with traditional teaching practices, but at its pedagogical core teaching has remained unchanged for
Most students. Textbook-driven lecture-like lessons, whole group instruction, and periodic quizzes and tests continue to dominate classroom instruction over the “more flexible and demanding pedagogies that include[d] substantial intellectual content and a deeper understanding of ideas, learning through inquiry, collaborative work, and ways of teaching that bridge[d] in-school and out-of-school worlds” (p. 111), proposed as those that will improve learning and provide the kind of knowledge and skills necessary for current broad societal demands. In a study of Tanzanian teachers’ instruction practices, Vavrus and Bartlett (2012) argue that despite the shift in policies towards learner-centered pedagogies in sub-Saharan Africa, the transmission model of teaching continues to prevail; they posit this as the result, in part, of situated knowledge in the adoption of new globally promoted pedagogies.

Moreover, the literature relates this intention to affect the enacted curriculum coupled with the recent wave of policy borrowing and lending to intensified reform processes in many countries. The borrowing or adopting policies that seem to work for other countries, a long existing phenomenon, even within countries, has intensified due to globalization and the emergence of an international policy sphere in which the quality of education systems is measured through regional and international assessments (Adams 2012). Many of these “best” policies are those that are applied in the higher ranked countries according to the results of these international tests, believed to work under the rationale that high performance is produced by them, independently, and assuming that these policies do not exist in countries with consistently low performance.

Heightening the urge to reform even more is the comparison against international benchmarks and against other nations that these international assessments promote (Benavot 2012).

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2 The most prominent of these are the Program for International Student Assessment (PISA) administered by the OECD and Trends in Mathematics and Science Study (TIMSS) and Progress in International Reading Literacy Study (PIRLS) administered by the IEA.
For both developed and developing nations, but especially for the latter, adopting policies from high performing nations provides a legitimized path to reform (Steiner-Khamsi 2004). Given this juncture, as ideographic (Larsen 2012) education comparativists claim, policy borrowing often occurs outside an analytical stance that considers the particularities of context and culture, both national and institutional, as important elements in the role of policies and organizational structures.

It is also this dynamic of seeing education systems through an international or regional comparative lens that has produced a discourse among the research community about high and low performers. Although comparison has been used for long by researchers to learn from other practices, much recent comparative research on education focuses on studying ‘high’ performing countries, given their stature and consistent high ranking in one or more international or regional assessments. Although critics of these international benchmarks argue that they promote a narrow vision of education and education quality (Heyneman 2013; Meyer and Benavot 2013), scholarship looks for answers to education problems in countries classified as high performers according to these benchmarks (see e.g. Choo and Darling-Hammond 2011; Darling-Hammond and Rothman 2011; Sahlberg 2011; Valverde and Schmidt 2000). However, while ‘high performers’ have taken center stage in much education research, low performing countries have been virtually ignored as a group, of which shared characteristics, when compared to ‘high performers’ could yield important insights for educational research.

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3 The U.S., for instance, has continuously made efforts to benchmark its curriculum by examining assessments applied in countries such as Japan, France, England, and Belgium (Phelps, 2001).

4 Such was the case of Japan and currently Finland and Singapore, which have obtained the highest mean scores in PIsA or TIMSS. In the case of regional assessments, much research in Latin America has concentrated on Chile’s education system, a country that has consistently obtained higher scores in regional studies of the Latin American Laboratory for assessment of the quality of Education (LLECE).
In conclusion, scholarship suggests that the adoption of curricular policies that seem to work for other countries or that are assumed best policies, without a better knowledge about how these interact in different contexts, added to the lack of further understanding of how teachers possibly enact the curriculum and the factors that have a role in such enactment, will more than likely limit change and improved educational outcomes (Gvirtz and Beech 2004; Honig 2006; Vavrus and Bartlett 2012).

Specifically, in mathematics education, the reform to the mathematics curriculum in many countries over the last century has been characterized by specific trends. Changes have sought to bring more challenging mathematics to the earlier grades (see Baker et al. 2010 for a study of the United States). More complex mathematics topics, higher order thinking skills, and applying and learning through problems and contexts have been incorporated or advocated in mathematics curriculum reform in several countries – mostly developed. But, here as well, questions about the level of cognitive challenge of the intended curriculum and the degree of divergence from it of the enacted curriculum brings to doubt the extent to which students have an opportunity to learn a more challenging mathematics curriculum. Once again, there is a need to understand how curricular governance systems support and engage teachers with the system’s educational goals in order to improve learning opportunities in mathematics. To this end, first and foremost, this study explores the enacting of the mathematics curriculum, not only in terms

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5 Although the homogenization of the curriculum in general is posited as part of a world educational culture, converging reforms in the mathematics curriculum have been shown to respond to both global influences, as well as the local histories and educational trajectories (see Meyer et al. 1992; Dale 2000; Valverde 2004).

6 A challenging mathematics curriculum is defined here as one that includes more complex or higher level mathematics topics and applies more complex thinking processes to the learning of all topics.

7 This is due partly to the association that mathematics has with science and technology, two areas considered essential to economic growth.
of its alignment with the intended curriculum, but with a focus on the OTL students are provided with.

1.2. Research questions and research design

Considering the issues stated above, this study seeks to address the following questions:

1. Concerning curriculum policy enacted in classrooms:
   a. What is the mathematics curriculum enacted by eighth grade teachers in high and low achieving countries?
   b. In what ways does the enacted mathematics curriculum of high and low performing countries differ?
   c. What is the relationship between the enacted curriculum and the intended curriculum in high and low achieving countries?

2. Concerning the mathematics enacted curriculum and various system and teacher factors:
   a. Do curricular governance systems differ between low and high performers?
   b. Are specific policy instruments and teacher factors associated with eighth grade teachers’ decisions in the enactment of the mathematics curriculum in high and low achieving countries?
   c. Does the association between policy instruments and teacher factors with the eighth grade mathematics enacted curriculum differ between low and high performing countries?

To explore these questions data from the Trends in International Mathematics and Science Study (TIMSS) 2011 are analyzed, focusing specifically on 8th grade mathematics. The national curriculum and teacher questionnaires from this study provide the data to explore the
intended and the enacted curriculum, as well as system and individual teacher factors. Of the more than 60 participating countries, 18 countries, including both developed and developing economies, are selected for the analysis and classified as high performing or low performing. Based on a national mean significantly and consistently above or below the TIMSS center point (500) across two or more TIMSS assessments, 10 countries are included in the group of low performers and 8 countries or territories in the high performers group.8

The first set of research questions produces the analysis and comparison of the enacted and the intended mathematics curriculum across these 18 countries based on the TIMSS mathematics framework. Both dimensions of the curriculum are captured through several variables, including content matter, performance expectations, instructional strategies, and instructional time measures – defined below. These variables also serve to explore the degree of correspondence between the intended and the enacted curriculum. Following the exploration of the mathematics curriculum itself, this study explores the association that different factors – system and individual teacher factors – may have with the enacted curriculum, comparing the association of each factor across and within the groups of countries. The first set of factors includes teacher education and professional development policies, as well as supervision and evaluation policies. The second set of factors includes variables for teacher individual characteristics, such as years of experience, subject matter knowledge, and beliefs about student learning. The problem posited for this second set of questions is to determine whether teachers’ level of enacting the curriculum is associated with these variables.

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8 Countries that according to average mathematics score in TIMSS 2011 are significantly above the TIMSS scale center point (500 points), according to TIMSS results, are categorized as high performing, while countries with mean scores significantly below the international scale center point are categorized as low performing.
1.3. Purpose

Accordingly, this study seeks to identify the mathematics curriculum – intended and enacted – in 8th grade classrooms across countries and distinguish similarities and differences between high and low performing countries. It also intends to assess the association of system and teacher factors with the enacted mathematics curriculum in secondary education schools, and compare these findings between and within groups of high and low performing countries. By using a comparative research design, the study seeks to advance existing knowledge about curriculum enactment and curriculum governance systems by looking at whether country profiles can be identified in relation to achievement.

This present study concentrates on the enacted curriculum. The degree to which intentions and enactment correspond is also analyzed, as an element considered important to reaching a country’s learning goals as well as to higher student achievement, but also as an important aspect to understanding teachers’ instructional decisions. This study especially seeks to describe and contrast the type of mathematics that is being taught in high and low performing countries, an issue that receives much less attention in existing research. Accordingly, the OTL in mathematics provided by teachers, rather than the degree of correspondence, is used as the main dependent variable. With this, the study aims at building on the knowledge found in the literature about the enacted mathematics curriculum. It inspects the relationship between the intended and enacted curriculum, by comparing high and low-achieving countries, in order to shed empirical light on the much-promoted global interest on the intended curriculum of high achieving countries, which tends to obviate the relationship between intention and enactment.

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9 The focus on these two kinds of factors does not suggest that only these are important. Factors such as school and community context, students’ own knowledge and experiences, and parents’ demands and expectations also influence the enacted curriculum in important ways. However, the system level variables are chosen along with teachers’ own factors as an initial exploration.
This research, focused as it is on curricular enactment, provides an opportunity to reevaluate the recent focus on policy intention.

The eighth grade – or equivalent – in the schooling progression has been chosen for analysis since a broader range of mathematics topics and areas are expected at this level, providing for a wider range of complexity – and thus a more revealing study of these two components of OTL. This wider range of variation in subject complexity provides ample opportunity to explore differences in high and low performing countries.

1.4. Conceptual framework

The curriculum, said to be framed by societal ideologies about the role of schooling and the nature of knowledge and learning (Apple 2005), is the fundamental structure defining students’ learning experiences. It defines the elements of schooling and the education system’s organizational structure. Therefore, how the curriculum is shaped has been explored extensively from sociological, political, economic, cultural and historical perspectives, and continues to be of interest to researchers. The study of the curriculum is complex, given the nature of the curriculum itself, for it is not a static element in an education system. The curriculum is reflected in and at the same time the result of a process in which various actors, institutions, elements, and dimensions are involved, and part of this complexity is observed in this study.

The curriculum is broadly defined as the sequence of content or subjects taught in school (Walker 2003; Jackson 1992). It establishes and reflects the goals and purposes of learning, and often the pedagogical approaches and teaching techniques that teachers are expected to use. The curriculum is reflected in several documents, such as official curricular plans and programs, textbooks, teacher guides, lesson plans, and assessments (Jackson 1992, Elmore and Sykes 1992,
Schmidt et al. 2001, Holmes and McLean 1989). Cuban (1992) and subsequently the studies that emerged with the Trends in International Mathematics and Science Study (TIMSS) in the 1990’s on curriculum and learning identified three levels of curriculum: intended, implemented and attained (see Figure 1.1). The intended curriculum refers to the elements of the curriculum that are defined at the policy level, and generally written in official curricular documents, in curricular guides, and national textbooks, for example. The intended curriculum reflects the knowledge and abilities the state (or decision-making level of the education system) intends for all students to acquire (Porter 2004). At another level is the curriculum as taught, or the opportunities to learn that teachers actually provide students, and it is referred to as the implemented curriculum in much of the literature (Remillard 2005, 213). Finally, the attained curriculum refers to the curriculum that is learned and is often measured through standardized assessments (Elmore and Sykes 1992; Cuban 1992).

![Figure 1.1: The levels of the curriculum](source)

This study focuses on the first two: the intended and the implemented curriculum. The latter, the process of implementation, has been studied from different perspectives. This dissertation assumes that implementers play an active role in implementing the curriculum, and therefore refers to implementation as enactment. Referring to teachers enacting the curriculum recognizes that teachers make instructional decisions that respond to specific student needs as
well as demands from the classroom, the school and the system. Thus, far from a solely top-down process, this study proposes curricular implementation as a process that should recognize and develop teachers’ autonomy and capacity to assess and respond to contextual demands while working to achieve the intended goals of the mathematics curriculum. Considering the curriculum through the lens of instruction implies a different way of looking at differences between intention and enactment. It moves away from a focus on strict alignment and auditing of differences, large or small, which are seen as weaknesses. The view of the curriculum as enacted proposes judging whether the goals of these two levels of the curriculum are convergent and work to mutually advance these goals.

In addition to the definition of the levels of the curriculum, scholarship also identifies its components, associating them to the provision of opportunities to learn – OTL. The curricular objectives, the subject matter, the cognitive processes, the time dedicated to teaching the content, and the resources employed in teaching are examples of these curricular components that determine the type of OTL made available to students. Since these elements vary across contexts, students’ OTL will also differ, and in turn, as research shows, create conditions for significant variation in learning outcomes. While some differences across systems are given by the different goals, structures, and elements established in curricular intentions at the national level, other differences are due to the possibilities enabled by the actors and factors that affect education. Concerns about the provision of equal or appropriate OTL for all students within the education system are addressed by researchers studying the association between components of the curriculum and learning.

To explore OTL, this study specifically focuses on 4 components: content, performance expectations, instructional strategies, and instructional time (IT). Content refers to the topics of
the subject matter, in this case mathematics; the term performance expectations is used to refer to
the cognitive processes students are expected to engage with as they learn the subject matter;
instructional strategies are the teaching techniques used by teachers; and instructional time is the
time teachers dedicate to the teaching and learning of the subject matter in the classroom.

Finally, the view of enactment as a complex process acknowledges the fact that
curriculum entails multiple factors that interact with teachers’ instructional decisions. In this
process, and assuming the relative autonomy of teaching practices in the classroom (Elmore and
Sykes 1992; Jackson 1992; Lipsky 1980), teachers are arguably the most important element of a
complex organizational structure that is composed of a set of interconnected elements at the
system, school and classroom level, as well as from the context in which it is situated (see
systems theory in Shafritz and Ott 2001). At the system level, the elements that are most directly
linked to teachers’ curriculum decisions are those that are intended to delineate and direct
teachers’ actions in the classroom, including the curricular policy itself and curricular policy
instruments. Examples of these are curriculum guides, textbooks, teacher education and
professional development, curriculum supervision, and evaluation policies. At the school level,
organization and managerial styles, school climate, the availability of teaching resources, and the
time teachers spend executing administrative activities are some of the elements potentially
related to instruction. At the classroom level, the curriculum interacts with elements such as the
knowledge, experience, beliefs and expectations of teachers, class size, the technology available
for teaching, and students’ background, prior knowledge, aptitudes and motivations. At the
community or societal level, curricular decisions are influenced by factors such as parents’ and
communities’ demands for students’ learning, parents’ education, income level and their degree
of involvement in their children’s learning, as well as the community’s engagement with the
school. This study takes system level variables, specifically curriculum-related policy instruments, and classroom-level variables, specifically teacher characteristics, and explores their relationship to the enacted curriculum.

Figure 1.2: Levels of influence on teachers’ actions.
*Source*: author’s elaboration drawing from the literature review.

1.5. Significance of the study

By studying the link between curricular intentions and the enacted curriculum and the various factors that are associated to the latter, this research contributes to the dialogue on policy implementation. Implementation of education policy, especially in low income countries, posits
many challenges. Policymakers, most of the time, focus on the desired outcomes of a particular reform and often fail to consider the processes or the actors involved in policy implementation in the specific context. Pressman and Wildavsky’s (1984) describe these complexities in the following words:

Policies imply theories. Whether stated explicitly or not, policies point to a chain of causation between initial conditions and future consequences . . . Implementation, then, is the ability to forge subsequent links in the causal chain so as to obtain the desired results. (cited in Nudzor 2009, p. 503).

The literature on policy implementation suggests that there are many elements that interact with, and are part of, this process and therefore influence the direction of policy. For one, while policymakers rationalize needs and policy solutions in certain ways and assume that they will be followed through, leading to foreseen outcomes, implementers, or rather, enactors at different levels conceive problems, needs, and possible solutions from different standpoints; these problems and possible solutions at the very least differ from those of policymakers (Elmore and Sykes 1992; Datnow and Castellano 2000; Honig 2006). These differing views drive enactment of policy in different directions. When the influencing factors -- and the ways in which they influence -- are unknown, policies are seldom designed in ways intended to facilitate and ensure enactment processes. Being able to understand these processes and the elements and links between them in this causal chain is a pressing concern in a time of increased accountability and demands for higher achievement. This point is further highlighted by the fact that in some education systems teachers are being asked to take more responsibility for student learning, without being provided adequate resources for the task or enabling to assume teaching in ways that truly promote such learning. This dissertation intends to be an initial exploration of which factors might help explain about policy enactment.
Furthermore, as education policies converge globally (see for example Anderson-Levitt 2003; Baker and LeTendre 2005; Meyer and Benavot 2013; McEneaney and Meyer 2000, Meyer et al. 1997; Steiner-Khamsi 2002, 2004), comparative research that focuses on implementation processes contributes to the understanding of how the “local” shapes the “global” (see for example Honig 2006; Jenson and de Sousa Santos 2000; Popkewitz 2005, Vavrus and Bartlett 2012). There are certain limitations to this research since the policy enactment process is not studied in depth. Qualitative research, including country or school case studies, would allow examining the implementation processes more thoroughly, and therefore enable the analysis of a broader set of organizational, contextual, and cultural elements. However, such an approach would require focusing on one or very few countries and would entail sacrificing generalizability and causal inference.

In contrast, examining the enacted curriculum as a dependent variable across different education systems with varying assessment outcomes, and commonalities and differences in curricular governance structures, provides an opportunity to learn about the possible strength of local influences and teachers’ own agency in defining policy processes. Finding similar policies or governance structures across low and high performing countries and differences in how teachers enact the mathematics curriculum in relation to curricular intentions would indicate the need to question the assumed effectiveness of global policies; differences in correspondence between intentions and enactment in varying governance structures would contribute to understanding the possible role of policy instruments. Moreover, similarities in the extent to which there is lack of correspondence with curricular intentions across countries with differing overall student learning results would provide elements to reevaluate the gap between intentions and enactment and to understand further teachers’ agency and instructional decisions. The
availability of TIMSS data, and the curriculum sensitive measures that are part of the TIMSS design, provide a unique opportunity for the large-scale, comparative study of curriculum policy enactment.

In addition, this dissertation seeks to augment the much needed scholarship on low performing countries – in many cases also developing countries – specifically about the mathematics curriculum. As in other areas of education research, the analysis of the mathematics curriculum in low performers is scant, and therefore, the discussion about the common characteristics across low performing countries, to the extent they exist, and how these compare to those of high performing, lacks empirical basis. This dissertation intends to overcome this knowledge deficit. This is especially timely and important because many contemporary policy prescriptions for improved outcomes in mathematics education are based on assumptions about key differences between the curricula of high and low achieving countries. These prescriptions aver that high achieving countries present a model that should influence curriculum policy in middle and low achieving countries. However, little empirical work has been carried out to document the specific differences and perhaps similarities between the patterns of intention and enactment in each group of countries.

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10 In Chile, Valverde (2004) looked at the mathematics curriculum using the TIMSS framework, while Benavot (2012) looks at the curriculum of developing countries in Latin America, Africa, Asia and the Middle East represented in curricular guides and textbooks.
Chapter 2. LITERATURE REVIEW

2.1. Introduction

The literature that supports and drives the research questions in this study pertains to the enactment of the curriculum, focusing specifically on the nuances of the mathematics curriculum. The concepts, theories, empirical studies, and methods reviewed in this chapter are used to articulate and justify the constructs and assumptions that are the basis for the study. They substantiate a series of hypotheses and advance the methodology used. While these constructs are discussed, the relevance of exploring their relationships in comparative perspective is noted.

The review of the literature begins with the discussion of the enacted curriculum as opportunity to learn (OTL) and the direct outcome of teachers’ decision making or teachers’ agency. It analyzes the different approaches to the study of the curriculum defined by teachers in the classroom, distinguishing between implementation and enactment; it also includes an examination of the mathematics curriculum deemed appropriate for the current time in order to better understand differences in OTL. This discussion is followed by the review of the factors that potentially influence teachers as agents creating OTL – enacting the curriculum. Individual teacher factors are examined first as one type of potentially influencing factors; these are followed system factors. System level factors are examined as part of a curricular governance system, leading into a discussion of the policy implications of the study and its comparative approach.

2.2. The enacted curriculum as Opportunity to Learn

Part of a curriculum defining process that begins with the identification of educational goals and directives for teaching and learning, the enacted curriculum is discussed and explored
in curriculum studies, organizational, and policy implementation literature. Curriculum scholarship has largely focused on exploring the kind of OTL that teachers make available to students and the associations that they hold mainly to achievement (Dindyal 2006; McKnight et al. 1987; Reys et al. 2003; Schmidt et al. 1997; Schmidt et al. 2002; Valverde et al. 2002; Valverde and Schmidt 2000; Westbury 1992). Literatures in organizations and policy implementation have been important in understanding teachers’ enactment of a curriculum in relation to the institutional context and the curricular governance system. These literatures are relevant to this study as it seeks to explore and compare across education systems the OTL that teachers offer students and their relationship to teacher factors and system policies.

In essence, the enacted curriculum refers to the content, skills, values and attitudes that accompany the ways in which teachers engage with students in the classroom and the specific instructional strategies, pedagogical approaches and time employed (Elmore and Sykes 1992; Cuban 1992; Porter and Smithson 2001; Schmidt et al. 2001). Although the intended curriculum is given much attention in theoretical and empirical curriculum scholarship, given that it reflects the purposes and directives of an education system, Porter and Smithson (2001) argue that the enacted curriculum is the “single most important feature of any curricular indicator system” (p. 2). It is the phase of the educational process where students interact directly with the content and therefore one in which the most focused learning is expected to occur.

Beyond this evident proximity of the enacted curriculum to the student, its importance is demonstrated in the relationship that it holds to student achievement (Gamoran et al. 1997; Schmidt et al. 1997, 2001; McDonnell 1995; Stein et al. 2007). Indicators of the enacted curriculum -- namely content, instructional time dedicated to topics, the pedagogical approach, time on task, and more demanding performance expectations -- have been shown to be
significantly associated with student achievement and achievement gains (McKnight et al. 1987; Schmidt et al. 2001; Valverde et al. 2002). Schmidt and colleagues (2001), in their comparative study of the mathematics and science curriculum and its association to achievement through curricular documents, textbooks and teacher data across TIMSS participating countries, conclude that the enacted curriculum shows the largest number of statistically significant associations with achievement. Paradoxically, it might seem, the enacted curriculum represents the most challenges in the realization of the learning goals in an education system.

The study of instruction as enacted curriculum can be linked to the concept of OTL. OTL as a concept originated with Carroll’s (1963) examination of student learning as a function of student aptitude and perseverance, and the amount of time allotted for learning according to the curriculum. Carroll argued that provided the time necessary to learn a specific task, which in turn depends on aptitude, students would succeed at learning. Accordingly, he termed the amount of time provided to students to learn the specific task OTL. Later, the Second International Mathematics Study (SIMS) of the IEA added as an indicator of OTL the specific content topics to which students were exposed (Husen 1967a and 1967b in Floden 2002; McKnight, 1979, Schmidt et al. 2011). OTL was used in SIMS and later TIMSS as a basis for assessing and comparing country performance in mathematics and science. In the 1990s, the TIMSS expanded the concept of OTL and used it to evaluate students’ learning in the light of what they actually had the “opportunity to learn”. Content topics, performance expectations, instructional time, and textbook coverage were all included in a model that determined students’ OTL, while examining student achievement (e.g. Schmidt et al. 2011; Thompson et al. 2012; Tornroos 2005; Wang 2010).
During this same period, OTL became an important indicator in studying schooling processes. Researchers, such as Porter (1991) and Oakes (1989), highlighted the need to focus on processes as education indicators, and not just on the inputs and outputs of schooling (see also Shavelson, McDonnell, Oakes, Carey, & Picus, 1987; Shavelson, McDonnell, & Oakes, 1989). Porter (1991), in particular, suggested creating a system of indicators about processes for three main reasons: 1) to know about the nature of the educational opportunity provided by schools to students as a direct policy output, 2) to have indicators of school processes that would allow the evaluation and monitoring of school reform, and 3) to be better able to identify the reasons for the failures to reach output goals. Available resources during teaching and instructional strategies were added to the indicators of OTL. Eventually, although instructional components (the enacted curriculum) remained the emphasis of the concept of OTL, other indicators related to input variables were also incorporated to the measure of OTL, such as teachers’ professional development, background and experience, and school resources (see Mo et al. 2013). These latter elements became increasingly important as OTL gained ground as a policy concept, particularly in the U.S. from the 1990’s onward (McDonnell 1995; Stein 2000).

Although there is no guarantee that opportunities will translate into learning, the latter can hardly occur in their absence. Ultimately, these are stochastic models which posit probabilistic relationships between curricular levels and OTL as a construct, considerably enriched and refined in terms of operational definitions from study to study, giving researchers the opportunity to examine the elements that, as a whole, promote or constrain the instructional process and analyze them in relation to what at the time may be regarded as necessary to provide quality education.
In the classroom, OTL is in direct control of the teacher (Porter and Gamoran 2002). In other words, teachers’ enactment of the curriculum translates into students’ OTL. Accordingly, this study looks at OTL in relation to teachers as curriculum enactors.

2.2.1. Approaches to the study of the enacted curriculum

How do teachers make instructional decisions, which translate into students’ opportunities to learn? There is consensus that teachers’ actions are part of a broad and complex system in which various actors, stakeholders, processes, and contexts are involved. However, researchers’ conceptualizations about their role in the process of curriculum decision-making have been subject to different views. Various policy implementation and organizational studies have aided the analysis of the curriculum and driven most of the research on the enacted curriculum.

From policy implementation to the enactment of the curriculum

The body of literature on policy implementation parallels to some degree organizational theory, which during the past century evolved epistemologically, providing much more useful schemes for understanding organizations. Similarly, policy implementation is currently an area of research that has gone beyond the simple relationships between policy and implementers.

According to Honig (2006), policy implementation, as a field, emerged in the 1960s. Then, implementation was seen merely as a top-down venture, in which policy designs should merely be distributed to the people putting them in practice, who, in turn, would deliver – or implement -- the policy and then be monitored in carrying out such tasks. That policy implementers did not deliver policies as prescribed was attributed to implementers’ own diverging interests from the policies’ goals, lack of will and capacity to carry on the tasks of the
policy. These reasons are still relevant to implementation analysis today; measures such as giving stronger incentives and providing clearer instructions were suggested to remedy the problem (Bardach 1977; Sabatier and Mazmanian 1979 in Honig 2006). Concerned mainly with the degree to which implementers adhered to policy, this approach to the study of implementation was referred to as the fidelity approach.

Honig (2006) identified a second phase in the field. Although the fidelity perspective prevailed, researchers’ view of implementers began to change. Implementers were seen not as individuals who lack motivation to change but as “engaged actors trying to cope with the sheer number of new policy requirements that converged on the “street level” and to reconcile work place demands with their personal and professional worldviews” (Honig 2006, 6). The macro and micro influences were recognized in policy implementation in what was termed mutual adaptation (Fullan and Promfet 1977). Nonetheless, as Honig pointed out, relationships between these two levels’ actors were still framed within a top-down command and control approach.

Towards the 1980’s, new understandings of the roles of people, places and policies in implementation emerged in the policy implementation literature. Policy tools or instruments in the form of mandates, incentives, capacity building, and systems change became central to promoting change in implementers, as much in actual policymaking as in research. However, researchers began to look at implementers’ agency in the response to policy directives, while also considering context, politics, culture, and histories (Honig 2006).

Currently, variation in the implementation of policies across localities is acknowledged and explained in relation to the complexity of systems. Beyond a concern with how to make implementers respond (top-down approach), researchers are concerned with how implementers understand, transform, adopt and make policy, something that relates directly to the enactment
approach. Honig sees in the policy implementation literature a growing attention to the interaction between policy, people and places in shaping implementation. This study considers these three elements to further the understanding of the issue.

Implementation of the curriculum: the fidelity approach

The specific literature on the enacted curriculum follows the path of the broader policy implementation literature. While initially regarding the implemented curriculum from a top-down approach concerned with the faithful representation of curriculum policy, views subsequently shifted to focus on successful implementation in relation to system conditions, followed by positions that regard teachers as main actors. I identified two main categories in the approaches and definitions found in the literature to study and define implementation: 1) fidelity and 2) teachers as enactors of the curriculum.

The fidelity perspective is especially concerned with alignment, or the degree to which the implemented curriculum corresponds to the intended curriculum11 (Fullan and Promfet 1977; Roach et al. 2008; Snyder et al. 1992). In this view, implementation seems more of an occurrence than a process. The fidelity approach problematizes implementation in the failure to provide students the OTL established in curricular intentions. Alignment as a research concept became prominent with the studies of the IEA, which, in differentiating OTL and their analysis, distinguished between the intended, the implemented and the attained curriculum. In the case of implementation, researchers try to establish through various mechanisms the extent to which teachers’ instruction is aligned with the intended curriculum (Livingston et al. 1986; Porter 2002; 11 Alignment refers to the correspondence between any two or the three levels of the curriculum (intended, implemented and attained). Alignment has been looked at using general or detailed frameworks and through the content matter identified in items in assessments, experts’ responses to whether certain content matter or content of testing items is expected to be taught, teacher surveys and other mechanisms.
Schmidt et al. 1997). The interest in aligning teachers to policy seems to be reinforced by the idea that the curriculum embodies the conceptualizations of the ideal citizens and of what is necessary to form them. However, critics of this approach, argue that it assumes teachers as passive deliverers of a curriculum and that it de-professionalizes their roles by holding them accountable only for transferring knowledge (Craig 2012). But the extent to which teachers are considered and can perform as professionals is limited in many education systems by factors within and outside such systems. Thus, the discussion regarding teachers’ role as mere implementers versus professionals is a more complex one.

Under this fidelity approach to implementation analysis, alignment between implementation and the intended curriculum is the indicator for successful implementation, and several studies take this stance. Vos and Bos (2005), for instance, compare the degree of alignment in the intended, implemented and attained mathematics curriculum in the Netherlands to the science curriculum and to that of Belgium using test items in the 1999 TIMSS. Although the authors recognize that stakeholders’ efforts, such as teachers’ professional development and in-service training, might have been helpful, they attribute the improved alignment between the intended and the implemented curriculum found in their analysis (in relation to that found in earlier studies) to a reinforced dissemination of the new mathematics curriculum. Clearly, the locus of action and change is placed at the system level, and not with the teacher (see also Bekalo and Welford 2000, Mitchell 1999). Although currently this and similar studies recognize that various factors impinge upon the enacted curriculum, the focus remains in the top of the system, where the fidelity approach posits primary agency lies, through policies that mandate or induce teachers’ actions. Accordingly, teachers are seen as subsidiary actors: primarily subjects of policy, not agents.
The reasons for alignment (or misalignment) and consistency in implementation across classrooms are sought in empirical and conceptual analyses considering structural or system factors. Conceptual studies speak of the various kinds of factors in the form of policy instruments that can influence alignment, such as mandates, incentives, capacity building and systems change, or their characteristics, including their prescriptiveness, clarity, availability, and consistency (McDonnell and Elmore 1987; Cohen and Spillane 1992). Empirical studies have focused on measuring and identifying the influence of specific policy instruments or system characteristics on aligned and consistent implementation. Stevenson and Baker (1991, 1996) and Westbury and Hsu (1996a; 1996b), for example, engage in a discussion based on empirical cross-country studies about the impact of curriculum control and centralization on alignment between the intended and the implemented curriculum.12 In the United States, Polikoff (2012) analyzes how aligned teachers are with state standards across states and describes the relationship between power, indicated in the use of rewards and sanctions, and tighter alignment.13

Several reasons are suggested in these and other studies for more or less alignment between intentions and enactment. Conceptual analyses suggest that the lack of appropriate guidance to teachers in a weak curricular governance system, the lack of clarity and specificity of

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12 Stevenson and Baker conduct a study across 15 educational systems to examine the relationship between state control and the degree of uniformity in the implementation of the curriculum. Their findings indicate that control of the curriculum at the national level, as opposed to the local level, accounts for higher uniformity in the content of teachers’ instruction in mathematics. They argue that institutional characteristics exert an important influence on instruction and that local control is associated with a higher degree of teacher autonomy. They further argue that in systems with local control of curriculum issues student, teacher and time factors exert an influence on instruction. Westbury and Hsu (1996) challenge Stevenson and Baker’s findings. Using curriculum courses as the unit of analysis instead of the system, they find no consistent relationship between central curriculum control and the consistency of teacher’s coverage of mathematics content, and argue that differences in variation in Stevenson and Baker’s study are due to differences in course offerings at the intended level. The discussion of the issue continued around methodological and measurement issues of the analysis.

13 Polikoff studies the attributes of policies- consistency, specificity, stability, power, and authority –, not the policies themselves. He finds that there is high variation in the attributes of policies across states and a small or moderate association between policy attributes and instructional alignment with standards and assessments; in some cases the association being negative.
curricular policy, guidelines and statements (Elmore and Sykes 1992), an overambitious and therefore unrealistic curriculum, the lack of instructional material for all schools or of adequate infrastructure to make use of these materials, the lack of coordination between curricular policy and the instruments themselves, limitations in teacher training and professional development programs (McEaneney and Meyer 2000), and that writers of policy statements, guidelines and textbooks address different audiences might have a negative impact on alignment. The prominent use of textbooks in teaching entails other possible reasons for divergence, such as the high costs of revising or adjusting textbooks after curricular reforms and the relative insularity of textbook writers. In addition, textbook editors’, designers’ and writers’ strong reliance on existing materials and past practices at the expense of the new ideas, content and teaching approaches brought with the curricular reform may contribute to distancing curriculum enactment from intentions.

In developing countries, the limitedness of resources and weaker governance structures are much more likely to exacerbate these conditions and lessen the degree of correspondence between the two curricular levels. In addition, the current continuous waves of curriculum reforms throughout many countries may further complicate enactment for teachers who have to constantly redefine their teaching concepts and practice, and perhaps learn new content, and who may not have the adequate and timely guidance and support.  

14 On the other side, higher curriculum control (Stevenson and Baker 1991; Gvirtz and Beech 2004), the level at which curricular policy decisions are made and implementation overseen (Schmidt and Prawat 2006), and centralization, as well as mandatory textbook, evaluation and accountability policies,

14 The following countries are examples of cases where more than one curricular reform has taken place in less than 8 years: England, in 2007 and 2013; Mexico, in 2010 and 2017; Chinese Taipei, in 2003 and 2008; Singapore, in 2008 and 2013.
discussed later in this chapter, are system factors found to have positive associations with alignment in empirical studies.

*Teachers as enactors of the curriculum*

The second overarching theme seen in the literature is that teachers, far from passive deliverers, have active roles in the making of the implemented curriculum (Clandinin and Connelly 1992; ILO/UNESCO 2008). Under this approach, teachers have been characterized in different forms, each with slight nuances, but all recognize enactment as a process in which teachers’ decisions are influenced by multiple factors. The most prominent depictions describe teachers as *agents in curriculum change and makers of curriculum*. Researchers within this body of literature are still interested in the reasons for the gap that exists between enactment and policy. However, instead of focusing on the system variables, i.e. policy instruments, the emphasis is made on the specific ways in which teachers act as *agents* of curriculum policy.

The basic premise of teachers as enactors of the curriculum is that the different levels, actors and agencies within a governance system have certain degrees of autonomy and authority in decision making (Lasky 2005; Priestly et al. 2012; Valverde 2004). As Branyon (2012) states, in spite of the existence of a national curriculum, teachers ultimately determine “the types of learning opportunities children experience in the classroom” (p. 40).

Priestley et al. (2012), like others (e.g. Campbell 2012; Biesta and Tedder 2006, 2007), tie the notion of curricular enactment to human agency. In their view, agency results from the interaction of individual and contextual factors, including available resources and structure, a view which, in contrast to other definitions, does not limit agency to an individual capacity or undertaking. Agency “emerges as individuals interact with the social (both cultural and structural forms as well as other people), practical and natural worlds” (Priestley et al. 2012, p.197) and
develops as individuals’ accumulate experiences. Teachers, then, exert agency within a frame of governance and institutional structures and curricular policy. Accordingly, while teachers may be accountable and respond to state policy, they also are able to use professional discretion insofar as they are committed to conducting their professional practice based on their values, convictions and beliefs about teaching and learning and have the capacity to deliver on such commitment (Campbell 2012, p. 184).

In this line of thought, Priestly et al. (2012) suggest the level of agency teachers can achieve varies across contexts depending on their ability to act on these values, beliefs and convictions and the possibilities or constraints offered by the system or external context. These elements delimit teachers’ alternatives, but alternatives are captured and weighed, and decisions are made by teachers. It is assumed then, that as teachers are held to higher accountability measures, such as teacher evaluations, including evaluations through student achievement, their discretion and therefore level of agency are more limited. On the other hand, teachers with strong beliefs and convictions may respond in ways that diverge from policy. In conclusion, enactment through agency seems to take focus on the internal processes of teachers as decision makers, while recognizing external influences.

Similarly, research that defines the curriculum at the instructional level as curriculum enactment understands it as a process in which teachers, in shaping the curriculum, draw on their identities, experiences and system and context factors (Honig 2006). Many empirical studies have delved into qualitative methods to see how teachers enact the curriculum and the kinds of factors that impact their decisions. Branyon (2012), for example, in examining through case studies the influence of internal and external factors on teachers’ instructional decisions in two Kenyan primary schools, finds that external factors such as parental influence, guidelines,
training and planning tables minimally or moderately impact teachers' decisions. Internal factors, on the other hand, such as teacher knowledge, attitudes, and self-perception all seem to have a high impact. In spite of the common curriculum, similar training in the use of guidelines, relatively equal knowledge of the national curriculum, and belonging to the same ethnic group, Branyon interestingly found that the opportunities provided by teachers and students’ learning experiences differed across the two schools.

Yet another explanation from the perspective of the enacted curriculum attributes teachers’ instructional decisions and actions to the interpretive and sense-making processes that take place as teachers engage with curricular policy, also known as the cognitive approach (Spillane 2000). In this line of study, teachers’ interpretation and understanding of curricular policy depends on prior knowledge and experience, and is likely to be followed by an adaptation process that responds to the particular teaching circumstance (Spillane 2000; Spillane et al. 2002). Interpretation can imply, although it is not limited to, a decoding of text, which in Nudzor’s words (2009), making reference to Trowler (1998), “is marked by the disputed and complex ways by which the policy messages and outcomes are interpreted by the policy actors and implementers in the contexts of their own culture, ideology, history, resources and expertise” (p. 78).

Regardless of the particular approach with which teachers, as main actors in curriculum implementation, are viewed, this second approach recognizes teachers as autonomous and professional individuals, whose identities, experience and context finally give shape to curriculum policy in the classroom. Placing a stronger emphasis on teachers, enacting of the curriculum assumes a more complex and interactive process than is rationalized in the fidelity
and alignment approach. However, although, theoretically, system complexity is recognized, few empirical studies have been able to explore the issue across a wider set of settings.

Under the concept of curriculum enactment, differences between implementation and curricular intentions can be expected to be more pronounced between regions whose cultures and identities differ from one another, even when curricular policy and policy instruments are similar. Differences should also be expected in teaching subjects that are ideologically contested in contrast to subjects for which there is broader legitimacy (Benavot and Resh 2003).

Although the view of teachers as enactors of the curriculum explains differences in OTL provided to students, it also makes certain assumptions that are worth considering. It can be argued that the emphasis on teachers as enactors follows, at least to a certain extent, from a vision of teachers as professionals; it is in this capacity that teachers would possess the following qualities, considered necessary to make better instructional decisions: a) the knowledge and abilities, provided by a quality teacher education and professional development; b) autonomy, which can only be developed through training, reflective practice and decision making, and c) an acknowledged and assumed responsibility in improving learning. In addition, for teachers to have the possibility to make adequate decisions, a developed and coherent education system that ensures curricular goals are established, approved and disseminated in effective ways and that the state has control of these and other processes involved in teachers’ decisions is necessary. However, the influence of elements outside and within the system, such as school principals and external supervisors that are not supportive of teachers’ role, may likely undermine teachers’ autonomy and professional decision-making (UNESCO 2017). Thus, seeing teachers as enactors should not imply that teachers make adequate instructional decisions, but that teachers’ decisions should be assessed and sought to be improved in relation to the factors that may influence them.
These considerations are particularly relevant in low performing countries, where teachers’ professional status is often undermined by inadequate organizational and institutional elements in the system as well as by the lack of resources and disadvantaged conditions in which they carry out their practice.

Teacher accountability also deserves greater consideration in the analysis of teachers as decision makers. Currently, education systems have established different measures to hold teachers accountable; teacher evaluations, student test scores or learning gains, school evaluation, classroom observation, internal or external supervision, and peer reviews are some of the accountability mechanisms used. Teachers may be held accountable through different mechanisms, to one or more actors, and for different purposes (UNESCO 2017). These elements of accountability systems affect teachers’ practice in different ways; teachers may see their autonomy reduced, focus their teaching on particular elements, most likely those on which they are being held accountable, or adopt new ways of teaching, particularly when feedback is incorporated into the system. When these systems have career implications or sanctions, they more than likely have a stronger and possibly negative influence on teachers’ instructional decisions. Overall, accountability systems, acknowledged as policy instruments intended to direct teachers’ practice, may hinder or promote better instructional decisions by teachers.

Furthermore, beyond the elements considered in the two approaches for the analysis of the enacted curriculum explored in this section, understanding teachers’ instructional decisions also requires further consideration of current global trends in education. First, the presence of market forces, charged with particular worldviews and interests, is becoming more prominent throughout education systems; market forces are increasingly involved in the production of textbooks and other teaching materials, as well as teacher training materials and teacher and
student assessments. Through these mechanisms, market forces influence teachers’ actions, as well as their educational ideas and beliefs. Second, the emphasis on the use of information, often obtained through evaluation processes, with the purpose of improving outcomes, has increased the prominence of accountability measures throughout education systems (UNESCO 2017). That schools and teachers are held to certain standards certainly has an impact on how teachers define their role.

2.2.2. The organizational theory perspective

While policy implementation and enactment research makes important contributions to the understanding of the policy instruments that impact the enacted curriculum, organizational theorists explain the disjuncture characterizing the functioning of institutional structures and institutions themselves in relation to wider social forces. Karl Weick sets the basis for the study of organizations in this vein in 1976 with the concept of loose coupling. According to Weick (1976) and Orton and Weick (1990) organizational units are simultaneously responsive or interdependent and indeterminate or autonomous. In the schooling context this means that while schools and teachers are rational and respond to the policies dictated from the core of policy decision making and to mandates given by the lower levels of authority, they also possess a degree of autonomy and an identity of their own, that will lead them to apply policy to local situations in varied and particular ways. Hence, differentiated implementation across education systems is expected to be found insofar as their structural features differ, e.g. according to differences in the content of the curriculum and the structure of schooling.

However, differences in implementation will also be due to the disconnectedness and autonomy of teachers’ actions. These actions are framed as the result of the interaction of their
individual histories, beliefs about teaching and knowledge, and the immediate internal and external school contexts. For example, when teachers feel their vested interest being threatened or their beliefs and ideologies do not correspond with those expressed in new policy, they will most likely resist to adopting the curriculum (Datnow and Castellano 2000; Huczynski and Buchanan 2001). Differences across systems, then, are expected from teachers responding to different policies as well as from the autonomy they exert as they engage with them. As Lipsky (1980), Meyer and Rowan (1977), and Fullan and Promfet (1977) argue, policies, in general, have a limited influence on practice.

Another vein of organizational studies, the neoinstitutional view, interprets the disparities between policy dictates and what teachers do from a broader perspective. According to neoinstitutional theorists, in spite of the continuous waves of reform, the changes in the curriculum learned by students across education systems have indeed occurred across education systems in the direction of policy change. However, rather than restrained in time and locality, change is observed as part of a worldwide phenomenon driven by universal ideals of society. Such phenomenon has produced isomorphic institutions and converging trends in curricular policy and content across the world. Although gaps between intentions and enactment are acknowledged, these are viewed as the space in the longer time span during which actors, including policymakers and teachers, and structures are adjusting to the changes driven by institutional and transnational forces in the broader social and cultural order (McEneaney and Meyer 2000). In sum, these perspectives in the field of organizational theory emphasize the element of rationality in decision making, the relative autonomy of enactors, and the importance of the wider institutional, social and cultural context in teachers’ decision making.
The two main approaches discussed in this literature review are considered in relation to their relevance in developing contexts. With a view of curriculum alignment as a necessary condition for high achievement, researchers concerned with fidelity focus on the policies that ensure teachers follow curricular intentions. As critics have argued, such approach fails to see teachers’ actions as the result of professional decisions that take place within the boundaries of their autonomy – however limited (Elmore and Sykes 1992; Jackson 1992; Lipsky 1980; Schwab in Clandinin and Connelly 1992), and the diversity of teaching situations they face. Indeed, teachers must respond to specific student learning needs and adapt their practice to particular contexts.

The view of teachers as curriculum enactors, on the other hand, considers that teachers, given their knowledge, experiences, and beliefs, are responsive to individuals and groups of students, and argues that teachers, as professionals, should make decisions to that end; in doing so, teachers redefine the curriculum (Clandinin and Connelly 1992). However, the recognition that the conditions for such professional decision making often don’t exist in some countries, particularly in developing ones, must be considered in the discussion. The fidelity approach requires that policies exist within developed and coherent education systems so that the effects of policies on the system itself and on teachers’ actions are as expected. On the other hand, professional decision making assumes teachers as professionals, which implies that they have the adequate technical abilities, but also that the status given to the profession allows them to recognize their importance, role and responsibility in student learning. In many developing countries such conditions in regard to the education system or the teaching profession do not exist.
2.2.3. The enacted and intended curriculum – methodological issues

The empirical study of the curriculum has made use of methods within both qualitative and quantitative research paradigms. However, one or the other has prevailed in each of the two approaches identified in this literature review. Empirical studies focusing on implementation through the lens of policy alignment use mainly quantitative methodologies, relying on the measurement of OTL. On the other hand, the analysis of teachers as curriculum enactors has mostly made use of qualitative methodologies.

The interest in studying what students have actually had the opportunity to learn in relation to the actual learning (and in turn to the learning intended) led researchers to give careful consideration to capturing the enacted curriculum. Particularly in studies that look at alignment – implementation from a top-down approach –, OTL is used to represent the implemented curriculum. As a construct, OTL has been operationalized in several ways: by measuring the amount of instructional time allotted to topics, the number of topics to be taught in a certain period - usually grade or school year - the amount of time spent teaching a topic, the number of textbook pages dedicated to a topic, the number of sections or lessons in a textbook that cover a topic, the time that students are actually engaged in learning a topic or time on task, the level of difficulty of instructional tasks, and the level of difficulty of learning goals for a given topic, for example (Mo et al. 2013; Porter 2002; Reeves and Major 2012; Schmidt et al. 1997, 2001; Valverde et al. 2002; Wang 2010). Similarly, the tools used to collect, measure and explore data on OTL have varied, with implications for the validity of the studies. Porter (2002) identifies 3 types of tools to measure content: surveys of teachers on the content of their instruction, content analysis of instructional materials (e.g. Benavot 2012; Schmidt et al. 1997, 2001; Valverde et al. 2002), and alignment indices describing the degree of overlap in content between the different
levels of the curriculum. The IEA’s studies, being curriculum based, have played an important role in this research.\(^\text{15}\)

Given the nature of the curriculum – constructed by several kinds of elements that need to be captured comprehensively yet informatively – specific methodological tools have been applied to the study of OTL and alignment. One of the methods used in the study of opportunities to learn is topic trace mapping, which is useful in examining the whole schooling progression and focusing solely on intended content topics.\(^\text{16}\)

Other methods for examining OTL and alignment were developed by Andrew Porter and colleagues (Porter 2002; Porter and Smithson 2001; Porter et al. 2007), including a two-dimensional matrix and content maps.\(^\text{17}\) The limitation of these methods is that they require detailed data on the level of cognitive demand employed by the teacher for each specific content topic. Moreover, their main purpose is to determine the degree of alignment.

Capturing and analyzing the enacted curriculum still represents certain challenges. It is difficult to faithfully measure the enactment of a curriculum that occurs throughout the year, or even more, from grade to grade as schooling progresses. Nevertheless, with limitations, teacher

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\(^\text{15}\) The IEA’s studies in mathematics and science collect data from teachers of assessed students on content taught, according to items on the test and to a curricular framework (McKnight et al. 1987), and on national curriculum policy. IEA’s studies SIMS and TIMSS facilitate and encourage studies of OTL across countries, especially with a comparative focus.

\(^\text{16}\) Trace mapping is used to explore the inclusion, introduction, duration and exclusion of a topic throughout the curriculum. Schmidt et al. (1997), for instance, did a comprehensive study of the mathematics and science curriculum in which they used the data gathered by TIMSS from several countries across grades 1 through 12. They looked into the number of topics taught by grade, the topics emphasized each grade, the flow of topics, and the most commonly intended topics at the focal grades and the duration of each, along with other associated themes of curriculum, such as curricular decision making and curricular organization, finding differences in all of these themes as well as notable similarities.

\(^\text{17}\) The two dimensional matrix captures the topics taught on one dimension and the categories of cognitive demand on the second dimension. The matrix is then reduced to proportions allowing comparison between manifestations of the curriculum, such as instruction, tests, and intentions. Content maps depict through contours the relative emphasis on content topics and cognitive demands.
questionnaires, teacher logs, video recordings and class observations still provide useful data to explore the enacted curriculum.

2.2.4. The Mathematics Enacted Curriculum

Mathematics, along with reading and science, is one of the most researched subjects in curriculum studies. The focus on mathematics stems from the value it is given as a basic subject, in which knowledge and skills considered necessary for personal, professional and economic growth are taught (Benavot and Resh 2003). In addition, mathematics is taught throughout the basic education cycle in almost every country (Kamens and Benavot 1991). Finally, while some studies point to great variation in the detail of both the intended and implemented mathematics curriculum world-wide (Valverde et al. 2002), other research acknowledges mathematics as a subject universally accepted in its knowledge base (Benavot and Resh 2003), making it an appealing subject to study further.

Moreover, the purpose of the study is to explore the enacting of the mathematics curriculum itself, and not only through the lens of alignment with the intended curriculum, and identify differences between low and high performers. Hence, this section provides a discussion on the mathematics curriculum in basic education, the changes it has undergone and the current views on what constitutes a cognitively demanding and therefore appropriate mathematics curriculum at this level.

The mathematics deemed appropriate for students at different ages of schooling have been subject to trends in ideologies on the purpose of education, the available knowledge, research findings, technological developments, and globalization effects. In the U.S., for instance, where most literature is found on the evolution of mathematics instruction, mathematics
curricula in the 19th and the beginning of the 20th century focused primarily on arithmetic topics (Baker et al. 2010). The pedagogical approach adopted at the time greatly emphasized procedural knowledge, computations, and memorization.18 The idea of a mathematics intended to develop students’ ability to think emerged well into the first half of the 20th century, but arithmetic topics continued to dominate the mathematics curriculum.

The second half of the 20th century is characterized by a shift towards a more challenging mathematics curriculum. Particularly in the United States, the concern over the loss of competitiveness in scientific and technological innovation highlighted the need to reform the mathematics and science curriculum. The establishment of national mathematics standards is the most prominent reform in this regard. More advanced topics were moved earlier in the schooling progression and new and more complex topics were introduced, while, in theory, drill and computational skills were deemphasized to give room to understanding of mathematical concepts and relations (Kelly 2009; Senk and Thompson 2003; Baker et al. 2010).

Other countries have taken a similar path. In a cross-country analysis of mathematics and science curriculum in TIMSS participating countries published in 1997, Schmidt et al. found that in the past decade many countries had introduced in their primary mathematics curriculum some basic knowledge of algebra and geometry. Reforms in Singapore, Denmark and the United States sought to increase student engagement and develop deeper understanding of mathematical concepts and abstract thought in problem solving (Schmidt et al. 1997; Dindyal 2006). Similarly, several Asian countries, particularly those that recognize themselves as knowledge based economies rather than natural resource based, have been shifting their curricular emphases toward critical thinking, technological modernity, and mathematical problem solving and away

18 For example, topics were introduced followed by examples to demonstrate the application of a certain rule or procedure, finalizing with a set of practice exercises (Baker et al. 2010; Senk and Thompson 2003; Spillane 2000).
from mainly skill-level instruction (Maclean 2001 in Lesh and Zawojewski 2007). Singapore, for example, in the last decades, seeking to grow its economy through technology, science and innovation, has centered mathematics curricular reform on challenging problem solving, the use of communication, and critical thinking skills; similarly, Japan has placed a strong emphasis on a demanding mathematics curriculum (Dindyal 2006; OECD 2011a, 2011b). And as Lesh and Zawojewski argue, despite the current prominence of high-stakes testing of basic competencies, many countries, including the U.S., have shifted back towards a curriculum that places greater emphasis on basic skills, while in high performing countries, such as Japan and Singapore, more emphasis is placed on higher order thinking skills.

Currently, curriculum experts encourage incorporating more advanced content and higher-order thinking skills into the basic education mathematics curriculum. Teaching what is referred to as a more challenging mathematics curriculum is considered by policymakers as essential for a country’s development, especially in terms of scientific and technological progress, it is also considered fundamental in enabling individuals to engage civically, socially and economically (Valverde 2009; Valverde and Naslund-Hadley 2010) in an era where being able to access and understand data and information are essential to understanding political, economic, and scientific developments.

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19 Lesh and Zawojewski (2007) claim that such focus on a curriculum that prioritizes creativity and innovation is largely due to the foreseen demand for workers with higher-order thinking skills and abilities (see also Goldin and Katz 2007).

20 The following are content areas and topics within them that are considered key to an adequate mathematics education: numbers, geometry, proportionality, algebra, calculus, and statistics and probability.

21 Higher-order thinking skills include teaching students how to formulate, analyze, interpret and solve problems, reason, make conjectures, and communicate mathematically (Benavot 2012; Valverde and Naslund-Hadley 2010). Cognitive expectations are intended to generate a deeper understanding of mathematics as well as the ability to apply mathematical concepts and skills to solve problems.

22 An increasing demand of technological, including computer based, skills accompanied by a decreasing supply of such skills in the U.S. from the 1980’s onward (Goldin and Katz 2007), for example, with considerable implications in the increasing wage inequality between skilled and unskilled workers, underscores this need. Accordingly, providing a more challenging curriculum responds not only to scientific and economic needs, but is aimed at reducing income inequality.
social and economic contexts, making informed decisions and participating in these fields. Consequently, mathematics curricular policy in many countries intends to give students opportunities to solve problems, reason, make conjectures, build arguments, justify solutions, communicate mathematically, and understand the concepts and principles that undergird procedures; all of this while deemphasizing procedural knowledge, drill and computation (Elliot and Kenny 1996; Spillane 2000). Moreover, linking mathematics to daily life situations and to other science concepts is considered a necessary element for developing mathematics skills (Spillane 2000).

Being exposed to a more challenging curriculum, one that includes more advanced mathematics content and higher order thinking skills, translates into higher achievement (Gamoran et al. 1997; Porter 1998; Porter et al. 1988; Valverde 2004, 2010). Several studies provide evidence of this (Brown et al. 2013; Schmidt et al. 2001, 2002; Valverde et al. 2002). Valverde and Schmidt (2000), for instance, compared the learning expectations held by high performing countries to those of the United States and found that higher achieving countries placed more emphasis on topics such as equations and formulae, proportionality, and congruence and similarity, and less emphasis on geometry topics. They also point out that higher performing countries covered fewer topics but in greater depth, supporting the argument that more demanding expectations in the curriculum yield higher student performance.

Furthermore, in a project to assess United States middle school students’ thinking and reasoning processes, Stein and Lane (1996) found that students who were provided the opportunity to work on more higher order thinking skills had higher achievement, including “sustained engagement in active inquiry and sense making” (in Stein et al. 2007, 358). Studies

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23 For this study, Valverde and Schmidt (2000) examine curricular documents and textbooks obtained by TIMSS across 21 high-performing countries and those of the U.S.
show that across countries, the amount of instructional time devoted to developing higher order thinking skills across topics, including topic-specific problem solving and mathematical reasoning, is strongly and positively associated with achievement gains (Schmidt et al. 2001).24

Clearly, with a growing understanding that countries must respond to these global challenges, intentions are likely shifting – or have shifted – in this direction in many education systems from the earlier grades. However, the extent to which higher order mathematics content and critical thinking, communication and other higher order thinking skills are actually present in the mathematics teaching and learning is unclear. To the extent that these higher-order thinking skills can be measured, it is highly likely that the mathematics curriculum follows these trends in most high performing countries.

Nevertheless, not all countries have articulated cognitively challenging mathematics knowledge and skills in their curriculum. In many Latin American countries, policymakers and academics appear to be concerned with the quality of the content of the mathematics curriculum, and yet, a review of curricular documents across several of these countries revealed that current curricular policies pay little attention to a challenging curriculum (Valverde and Naslund-Hadley 2010). Learning objectives in these curricula are ambiguous, seldom operationalized, and lack academic rigor and more complex performance expectations; discussions often remain on the philosophical and ideological levels, lacking any empirical evidence (Valverde and Naslund-Hadley 2010). A review of curriculum policy in Chile, a country in which average educational achievement is higher than many other developing countries, revealed a less demanding curriculum than that of other countries participating in TIMSS (Valverde 2004).

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24 Schmidt et al. measured the amount of instructional time devoted to higher order thinking skills, using as an indicator the amount of textbook space devoted to these. They focused on comparing components of the curriculum to 8th grade mathematics across TIMSS 1999 participating countries.
Finally, in spite of existing research showing significant relationships of certain curriculum elements and higher achievement, there is little evidence that one method of instruction, either as promoted by policy or as adapted by teachers, will lead to higher learning outcomes over others. In this regard, the 1999 TIMSS video study is not able to identify a particular teaching method across the high performing countries or characteristics common to all of these. As Schmidt et al. (2001) and others argue, context matters in how the different elements of the curriculum impact achievement.

2.3. Individual and experiential factors that influence teachers’ decisions

The literature focusing on teachers as agents of the enacted curriculum reveals much of the interaction that occurs between the defining features of curricular policy and teachers’ autonomy. Teachers, as actors in loosely coupled systems, are directed and influenced by policies and free to respond in ways that are congruent with their perception of student needs and the school and community context, as well as with their own ideology, beliefs about teaching and learning, subject matter knowledge, understanding and interpretation of policy, professional identity and teaching experience (Porter et al. 1988; Clandinin and Connelly 1992; Stein, Baxter, and Leinhardt 1990). Several studies have focused in the latter elements – teacher factors and teaching experience – and whether and how they influence the enacted curriculum. That said, this literature is limited; some of these elements are rather explored in relation to alignment while others directly in relation to achievement.

Associated with teacher quality, teacher knowledge is a factor considered fundamental in the definition of teachers’ decisions and instruction or OTL (Hill and Charalambous 2012; 25 The TIMSS 1999 vide study analyzed a random sample of 100 eighth grade classrooms from seven countries – Australia, Czech Republic, Hong Kong, Japan, Netherlands, Switzerland and the United States.)
Manouchehri and Goodman 2000). Teacher’s knowledge of the subject matter, determined in great part by teacher preparation, influences teachers’ interpretation and adaptation of curricular policy, specifically of what and how to teach. For example, in their review of studies carried out in the United States to examine the correspondence between the written curriculum and actual practice, Stein et al. (2007) found that teachers’ use and adaptation of guiding materials varied, and that this variation was identified with differences in subject matter knowledge. Teachers tended to favor topics with which they were more familiar.

The importance of subject matter knowledge becomes more evident following curricular reform. Specifically, in the case of mathematics, in a qualitative study of the implementation of curricular reform across several United States districts, Spillane (2000) found that teachers attend to reform descriptors or concepts that are more familiar to them with more frequency. *Problem solving* and *hands-on*, for example, are concepts more common in their references than the recently introduced *communication* and *reasoning*. Spillane argues that this can also be attributed to abstract concepts being more difficult to grasp than more concrete ones; in either case, the intersection of higher difficulty and teachers’ unfamiliarity with the new and more complex concepts would only emphasize teachers’ distance from these concepts.

Furthermore, Spillane (2000, 155) found that teachers tend to focus on the procedural knowledge of mathematics instead of actual mathematics concepts and knowledge. In his words “[t]heir understandings were firmly grounded in a procedural conception of mathematical knowledge and a computation-focused perception of doing mathematics.” Research findings on pre-service teachers indeed indicate that while teachers know rules and procedures, they often lack knowledge of concepts and reasoning skills (Wilson et al. 2001). Through the analysis of students’ notebooks in Peru, Cueto and Leon (2006) found that teachers tend to overemphasize
the least challenging topics in the curriculum (in Valverde and Naslund-Hadley 2010), while teachers in Panama and Costa Rica were found to have important weaknesses in their knowledge of mathematics and mathematics pedagogy (Sorto et al. 2008 in Valverde and Naslund-Hadley 2010). These deficiencies have a negative effect on teachers’ practice.

Teacher beliefs and values is another factor on which the literature agrees strongly influences the enacting of the curriculum (Feyzioglu 2012; Haney et al. 2002; Muncey and McQuillan 1996; Suurtam and Gravies 2011). A qualitative study conducted by Priestly et al. (2012), in which they compare teachers enacting of the curriculum in two schools considering their individual experiences and beliefs about teaching, illustrates how beliefs can shape enactment. One teacher believed that it was important to engage students in learning, but he also believed teachers’ role in such was to deliver knowledge, while students should only be passive receivers of it; he was convinced that in order to engage students it was necessary to teach towards performance and have discipline in the classroom. According to the authors, these beliefs were reflected in the more traditional and lecture like classroom instruction of the teacher. Priestly and colleagues describe his response and policy enactment as practical and his capacity for agency constrained, and trace his beliefs to his own past career trajectory, confined to traditional experiences within educational institutions. A second teacher stood out in contrast. Her beliefs are summarized in her assumed responsibility as a teacher to unlock students’ innate potential, while her teaching reflected clear efforts to engage students to promote dialogue and learning. Priestly and colleagues also link her beliefs to her experience, including having worked as a volunteer with playgroups, her own learning at school and having children. Although generalizing from these case studies is problematic, they shed light on how beliefs and values
can determine the kinds of interactions that will take place in the classroom between teachers, students and content. Insofar as knowledge, beliefs and experience differ from one teacher to another, curriculum enactment will vary even in settings where teachers are accountable to the same policies and follow the same instructional materials (see, for example, Branyon 2012). Also in high performing countries, teachers tend to possess better content knowledge, whereas in low performing nations teachers may believe students ability to learn in different ways is limited. Nevertheless, strength of the influence of knowledge, beliefs and experiences, or lack thereof, in teachers’ decisions might be constrained or motivated by structural and system factors. Other factors (e.g. teacher professional identity in Montgomery 2012 and Lasky 2005, and experience in Priestley et al. 2012 and Li et al. 2013) are suggested as influencing teachers’ decisions in the enacting of the curriculum. Empirically, however, they have been scantily explored. Moreover, their impact on teachers’ instructional decisions in relation to system elements was not identified in the literature.

2.4. Teachers’ decisions and system and structural factors

As discussed previously, although the enacted curriculum is concretized by teachers’ decisions, their actions are framed within an organizational structure and a system of curriculum governance.26 Being that educational governance structures and policy instruments are set in place in forms believed to better direct and influence the delivery of education in line with the established curricular goals, an effective curricular governance system, according to curriculum

26 Curricular governance systems articulate the structure of schooling (e.g. grade structure and decision making centers), the policy instruments (e.g. curriculum and textbook policies), and the actors that have – or are meant to have – a role in what gets taught and how, and they are formed by formal and legal elements and structures as well the agents and their interrelationships (Valverde 2004).
scholarship (Elmore and Sykes 1992), is one in which the enacted curriculum is closely aligned with curricular policy. As a basic premise, this requires that all efforts, including policy instruments and structure are coordinated around common objectives (Elmore and Sykes 1992), a phenomenon that is referred to in the literature both as convergence and coherence (Schmidt and Prawat 2006; Resh and Benavot 2009). But beyond this premise, the influence of the governance structure, specifically in relation to the degree of centralization, and the use of specific policy instruments on curriculum implementation and alignment is explored in several empirical studies. Clearly, the national context and the characteristics of an education system do have an impact on the enacted curriculum (Wiseman and Brown 2003).

Researchers tend to agree that governance systems are becoming increasingly more complex (Resh and Benavot 2009; Valverde 2004). This is due to changing notions of education quality, more participatory processes of decision making, new structures of accountability and evaluation, and the expertise of external agents and agencies. There is less agreement on the extent to which these changes are creating isomorphic governance systems and structures. While some educational researchers argue that the emergence of a system of global governance, discussed below, diffuses policies across nations, leading to educational standardization (Meyer and Benavot 2013), others show that the adoption of global policies within distinct national and institutional cultures results in wide variation of educational governance systems (Valverde 2004; Watson 2009). From these seemingly contradictory but not mutually exclusive arguments, commonalities (e.g. in the selection of policy instruments) in governance systems across nations are assumed.
2.4.1. Policy instruments and curriculum control

The selection of certain policy instruments to direct teaching underlies a claim of what instruments or resources are necessary to ensure that students learn what they are intended to (Valverde 2004). It has also been associated with the intention of education leaders and policymakers to control or regulate teachers’ actions. Gvirtz and Beech (2004), for instance, discuss this use of policy instruments as a measure to ensure that policy is enacted in the classroom as a form of regulation, defining such as the “processes through which curricular policy is transmitted to the agents who have to put it in practice” (p. 372). Thus, instruments of curriculum regulation such as mandatory textbook, teacher education and professional development, and supervision and evaluation policies guide while at the same time exert teachers to follow curricular policy. Empirically, a positive relationship between some of these instruments and teachers’ enacting of the curriculum is found in the few studies on the issue, although most research has focused on their association to student achievement.

The textbook, for example, is one of the more extensively explored policy instruments. It is examined as a representation of both the intended and enacted curriculum and associated with student attainment (Bikai et al. 2013; Haggarty and Peppin 2002; Schmidt et al. 2001; Valverde et al. 2002). Nonetheless, its impact on the enacting of the curriculum is assumed and suggested from the positive association found between textbook content and achievement.27 Schmidt and colleagues (2001), for instance, using TIMSS 1995 data, rely on mathematics and science textbook content, particularly the space allocated to topics, to determine the association between

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27 Schmidt et al. (1997) and Valverde et al. (2002) examine the mathematics curriculum across countries through an extensive review of textbooks and its association with achievement. A positive and significant association is found for mathematics topics.
instructional time and the emphasis teachers place on topics, on one side, and student achievement on the other.

Teacher education, a part of the curricular governance system, has garnered increasing attention in scholarship in the last couple of decades, just as education reforms across the globe are increasingly focusing on raising teacher quality by making changes to teacher recruitment, preparation and professional development programs (Desimone et al. 2006; Schmidt et al. 2011; Tatto et al. 2008; Tatto 2008; Tatto and Senk 2011; Evan and Loewenberg Ball 2009; Payne and Zeichner 2012; Robertson 2012; Blomeke 2012; Shinn 2012). Teacher quality is considered a necessary condition to improve educational outcomes, and although there is no agreement in the literature as to what teacher quality means (Payne and Zeichner 2012) or how it is sought (Tatto and Plank 2007), there is an emphatic understanding that teachers’ content and pedagogical knowledge matters to instruction and to achievement.

Research in this matter covers several aspects of teacher education, including teacher recruitment, professional development programs, teachers’ OTL, and teacher credentials. Of particular interest to this study, as it relates to teachers’ knowledge and skills, are future teachers’ professional development and OTL. Blomeke (2012) identified that although there was heterogeneity in mathematics teacher preparation programs across 15 countries,28 it was not as pronounced as expected, identifying four classes of teacher OTL and a considerable degree of homogeneity across countries. Moreover, Blomeke found a high level of homogeneity within several nations. As expected, mathematics teacher preparation programs vary across countries (Blomeke 2012); while some highlight mathematical knowledge, others focus on pedagogy,

28 The study uses data from the Teacher Education and Development Study: Learning to Teach Mathematics (TEDS-M) study under the supervision of the IEA, which gathers information on secondary education teachers and teachers’ knowledge, pedagogy in mathematics and their learning experience in teacher education programs.
consider teaching for diversity or emphasize providing actual teaching experience. And although some studies suggest that deep mathematics content knowledge may be the more important factor (Blomeke 2012), others point to both knowledge and pedagogical factors (Clotfelter et al. 2007; Sowder 2007). Undoubtedly, the grade level matters to how much mathematics content knowledge teachers need to have; as the mathematics topics to be taught are more complex, a deeper knowledge of the subject may be required. This and other studies reflect a heightened discussion about the type of learning and experience that future teachers obtain through these programs and their relationship to achievement.

Similarly, much of the analysis of professional development programs is concerned with the types of activities and the extent to which they enhance teachers’ instruction and student achievement (Garet et al. 2001; Desimone et al. 2002; Li et al. 2013; Loucks-Horsley and Matsumoto 1999). According to Li and her colleagues’ (2003), the time Chinese teachers’ spent acquiring additional mathematics content knowledge or mastering mathematics teaching techniques or strategies, the use of technology in instruction, or how to evaluate students’ learning is positively and significantly associated with teachers instruction, although the correlation is moderate.²⁹ Other studies show that professional development that improves teachers understanding and use of curriculum materials has a positive impact on teachers’ practice (Cohen and Hill 2000; Roehrig, Kruse, and Kern 2007). Studies of professional development that focus on subject matter content and pedagogical knowledge – how students learn the content – have been shown to be associated with the enacting of the curriculum (Garet et al. 2001; Desimone et al. 2002; Li et al. 2013).

²⁹ These activities were all analyzed under one variable and therefore an activity of higher possible influence is not identified.
Teacher collaboration is another policy instrument that positively influences teaching and can be used to support the enacting of the curriculum. According to the literature, teacher collaboration provides teachers with opportunities to share, discuss, and reflect collectively on ideas and teaching strategies to improve their practice and solve instructional problems they face in their everyday settings. This is especially so when teacher collaboration is designed and directed in a way that engages teachers (Li et al. 2013; Stein and colleagues 2007; Suurtam and Gravies 2011). According to Suurtam and Gravies (2011, 357), dialogue and collaboration help teachers “derive support, motivation and direction from one another.” Nevertheless, some experts and empirical studies suggest that teacher collaboration, even informal collaboration, must be developed and sustained as part of the school culture, rather than imposed on teachers, in order to have a positive impact on teachers’ teaching and learning (Hargreaves 1992, 2009; Hargreaves; 2013). In spite of this, Thornton (2006) proposes the supporting policies for formal teacher collaboration programs as a catalyst for meaningful teacher collaboration. Although the literature agrees that teacher collaboration, considered in most studies a component of professional development, improves teachers’ practice teachers (Hargreaves 2009; Lachance and Confrey 2003; Li et al. 2013; Rosenholtz 1989; Westheimer 1998), empirical studies that seek to understand the association between teacher collaboration and the enacted curriculum, especially as it relates to different contexts are absent.

Similarly, assessments, supervision and other forms of evaluation of curriculum enactment are intended to impact instruction. Supervision, as a hierarchical act of control and inspection, is viewed with reticence by teachers and, according to Kutsyuruba (2009), has little effect on instructional practices. However, the literature identifies a more useful approach to supervision, one which is meant to support teachers through a feedback process as they enact the
curriculum through collegiality, collaboration and reflective practice (Beach and Reinhartz 2000 in Wanzare 2012; Kutsyuruba 2009; McQuairre and Wood 1991; Sergiovanni and Starratt 2002; Wanzare 2012). Few empirical studies have been able to measure the impact of supervision on instruction, although teachers do perceive a change in reflexive processes linked to supervision practices, something that is more likely occurring in developed countries.

Assessments, either national or regional, as an instrument intended to measure educational progress and the quality of educational systems, are also used to change teachers’ instructional practices (Palmer and Snodgrass 2011). Several studies show they have an impact on teachers’ enactment of the curriculum, particularly when they are high-stakes. Following international trends, the use of national assessments has expanded across nations, while some actors have raised concerns over their role and possible effects on teaching. While advocates argue that testing makes teachers more responsive to curriculum standards and seek more effective ways of teaching, critics contend that testing narrows teachers’ focus to tested content, excluding from instruction important cognitive processes that cannot be captured through tests (Hamilton and Berends 2006; Gunzenhauser 2003; Palmer and Snodgrass 2011). In a study of the impact of standards and accountability measures, Hamilton and Berends (2006) find the following changes in teaching practices are related to the use of assessments: elementary school teachers allocate slightly more time to mathematics and English, the core subjects assessed; they seek different teaching tools for instruction; they focus more on tested topics; and they use assessment styles similar to those of the tests.

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30 This is a RAND study that measures specifically the impact of standards-based accountability (SBA) provisions under No Child Left Behind act of 2001 in the U.S. The SBA system involves content achievement standards, statewide tests, and systems of intervention and consequences associated with the tests’ performance (Hamilton and Berends 2006).
In contrast, Firestone and colleagues (1998, 2000) contend, from the study of lower secondary teachers’ reported changes in England, Wales and two states in the United States, that assessments have a limited impact and only under particular circumstances. Assessments have to be intended and designed to affect instruction, by being aligned with curricular standards and other instruments. Although their findings are inconclusive given the limitations of the study, Firestone and colleagues argue that teachers’ fundamental approach to teaching, which lacks in many cases deeper conceptual understanding, remains unaltered by assessments. They suggest, among other things, that the teacher beliefs about teaching and learning influencing instructional practice can hardly be changed by assessments.

2.4.2. Curriculum governance structure

Curriculum regulation is associated with more centralized systems. According to Resh and Benavot (2009), centralized systems usually have a detailed curriculum along with mechanisms to oversee its implementation, such as testing, inspections, and highly regulated teacher-training programs. Partly for these reasons, curriculum centralization has been associated in empirical studies with curriculum convergence and uniformity (Benavot and Resh 2003). Several studies looked at the impact of curriculum control and centralization on the alignment of the intended and the implemented curriculum (Stevenson and Baker 1991, Westbury and Hsu 1996, Schmidt and Prawat 2006). While some studies support the claim that higher control translates into higher levels of convergence or consistency in the organization of the curriculum (Stevenson and Baker 1991, Resh and Benavot 2009), other findings indicate that control at the national level is not a necessary condition for convergence, but rather that at some level –
national or local – policy is articulated in coherent terms (Westbury and Hsu 1996; Schmidt and Prawat 2006).

Overall, different forms of control in education are not consistently found to be associated with higher achievement. Few studies have explored this issue in great depth. Wiseman and Brown (2003), for example, using TIMSS 1999 data measured control through teachers a choice over the content matter they teach and the textbooks they use in class and associated it with achievement. They found that curriculum control was not consistently positively correlated with achievement in either mathematics or science, and in some cases the association was actually significantly negative, noting how curriculum control can be undermined by teaching autonomy. This study highlights the importance of the interaction between the curriculum governance system and its components, context, and teacher factors; it also shows that the role of the same policy instrument in instruction varies across educational systems, something to highlight as policies travel across systems with the expectation of similar results, only to be understood, interpreted and adopted differently by educators.

2.4.3. **The influence of the global policy environment on national policy**

The role of policy instruments in the enactment of the curriculum across contexts and how these relate to achievement is particularly relevant in a global context of educational policy borrowing and lending and a recent prominence of comparison and international benchmarks. Lingard and Rawolle (2010, 33) argue that comparison globally has become central to a new form of governance and the emergence of a global educational policy field. Nation states alone no longer shape policies in education or in practically any other field. A shift from a national sphere of authority to an international sphere has taken place, as some would argue, driven by
international organizations in a discourse that places education as the main route for economic growth (Resnik 2006). It is from this space that education policy is now conceptualized, produced and diffused (Rizvi and Lingard 2010). This increasingly transnational sphere of education has found new ways to define education quality, or at least one that is said to correspond to the needs of the 21st century (Adams 2012; Sahlberg 2011; Valverde 2009). Transnational governmental organizations such as the OECD, UNICEF, UNESCO, and the World Bank, as well as non-governmental organizations, such as the IEA, have become leading voices in the redefinition and reconceptualization of education quality (Resnik 2006).

International assessments play an increasingly prominent role in this global education sphere. During the past 20 years the number of countries participating in them has increased significantly, not only among developed countries, but also among the developing countries (Kamens and Benavot 2011). They exert influence even on countries that participate intermittently or not at all: the PISA and TIMSS standards and testing frameworks are often routinely examined by curriculum developers (Wolf 2006; Ferrer y Arregui 2006). For some countries participation has resulted in changes in curricular policy, e.g. Germany (Ertl 2006), or served to legitimize curricular reform, e.g. Turkey (Gur et al. 2012), but for all it has meant the inclusion in an international context that has implications beyond the assessments themselves and the field of education. Developed by organizations such as the OECD, the IEA, LLECE\(^{32}\) by UNESCO and other regional organizations, international assessments set the grounds for comparison as they tell countries of the relative “quality” of their education systems in a world

\(^{31}\) According to Kamens and McNeely (2010) by 2010 about a third of the world’s countries participate in international assessments.

\(^{32}\) The Latin American Laboratory for Assessment of the Quality of Education (LLECE) is a network coordinated by UNESCO that focuses on the assessment of quality of education in Latin America (http://www.llece.org/public/content/view/8/3/). SERCE is one of the evaluations carried out by LLECE.
where educational outcomes signal global economic competitiveness (Kamens and Benavot 2011). International assessments, such as PISA, TIMSS, PIRLS, and TERCE, measure achievement in mathematics, science and reading of basic and secondary education students.

With this, international testing regimes define global benchmarks against which countries are increasingly inclined to measure themselves, narrowing the focus for educational improvement, with adverse implications especially for developing countries. Kamens and Benavot (2011) claim that participation in international assessments, given priority over regional assessments, means for developing nations losing the opportunity to evaluate themselves and make use of comparable information that reveals the possibilities of their realities. As this broader non-comparable international sphere becomes the space in which these countries situate themselves, the adoption of policies considered effective in developed countries may become the norm, even when developed and high performing countries continuously change these world-best policies seeking to improve their outcomes (Kamens and Benavot 2011).

Thus, as countries are influenced by this trend and look for answers to address education challenges and the resulting need for education reform, curriculum governance systems across countries seem to be converging. Indeed, along with the emphasis on cross-country comparison, international assessments have provoked the policy borrowing and lending that is widely acknowledged as part of the transnational educational sphere (Steiner-Khamsi 2004). As comparisons bring on both external and internal demands to improve education systems, the pressure for countries to learn and borrow from education systems elsewhere is tremendous. For both developed and developing countries, “lessons” given by what appears to work in other nations, often justify and legitimize education reforms (Steiner-Khamsi 2004, 4-5), as in the case of Turkey (see Gur et al. 2012), Finland and England (see Grek 2009), and in some cases trigger
or contribute to discussion and curricular reform, as in the case of Germany (see Ertl 2006; Neumann et al. 2010).

For less developed countries the pressures to reform, and reform in specific ways, come from the international community (Steiner-Khamsi 2004, 4-5). Hence, countries increasingly emulate policies that have been ‘proven’ to work, which in the eyes of policymakers are those policies that exist in high ranking countries. In the 1980’s, for instance, the United States adopted many of the policies of high ranking Japan, such as the prolongation of the school day and a longer school year (Arnove 2007). Furthermore, as Dobbins and Martens (2012) show, the French 2010 education reform, triggered in part by the poor performance of students particularly in PISA 2009, was deliberately modeled after the Finnish education pedagogical methods and policy instruments, including more flexible classes tailored to students’ needs and giving greater autonomy to schools.

In this context, the direction of curriculum reform responds to this adherence to this global dynamic of world-class policies, rather than a deep analysis of the specific context, needs and conditions under which particular policies can produce desired results. Not surprisingly, diverse nations, high and low performing, as well as developed and developing, will increasingly show commonalities in terms of curricular policy and the policy instruments of their curricular governance systems. However, outcomes clearly differ.

It is not only policymakers seeking policy solutions and ways to legitimize education reform who look towards high achieving countries. Many policy-oriented studies focus on high achieving countries as examples to be emulated or as representative of best practices (Bishop 1993; Mullis 1997; Valverde and Schmidt 2000; Phelps 2001). Gamoran (2001), for instance, explores Japanese mathematics instruction and compares it to that of the United States. The
Finnish education system, among the highest performing systems in PISA, has been examined in comparative studies by numerous scholars (e.g. Benavot and Meyer 2013; Ceylan and Abaci 2013; Hausstatter and Takala 2011; Kim et al. 2009; Beese and Liang 2010; Ammermueller 2007; Basl 2011; Liang 2010). Undoubtedly, there is a tacit consensus that a world-class education can be modeled along the lines of the highest performing countries.

Similarly, in curriculum policy research, the focus has been on improved performance, with the assumption that the best features of curriculum policy in the higher performing countries are either absent or deficient in the lower performing ones. Many researchers, for instance, comparing the United States to high performing countries, assumed that the existence of a national curriculum or curricular standards is a necessary condition for high performance. Historically, however, a national curriculum has also characterized many low performing countries. Content and performance standards, time allocation, and structure are some of the elements that, as identified in high performing countries, are seen as ideal. Nevertheless, we know little about the extent to which the same ideal elements are present or absent in the curriculum of low performing countries or whether these elements have existed for long. Moreover, little is known about the extent to which these elements defined by intended policy are actually enacted in the classroom.

2.5. Summary and conclusions

This chapter, which explored literatures on curriculum, curriculum governance systems and policy instruments, and teachers as agents in the implementation of the curriculum, depicts the context in which teachers enact curricular policy. Decisions made by teachers on what and how to teach can be seen as resulting from an interaction between: 1) teachers’ knowledge,
experience and beliefs about teaching and about their students; 2) the school and community context, including students themselves and teaching resources available; and 3) the curricular governance system, which includes curriculum, directive and accountability policies. The studies discussed above reveal the tensions created as these elements interrelate, resulting in an enacted curriculum that, often, does not correspond or represent intended curricular policies. Evidently, if teachers are expected to be responsive to students’ particular needs and to the demands of a local context, teachers must do more than follow curricular intentions.

While a governance structure that includes curricular policy and policy instruments may be the initial frame of the curriculum, at the time of enactment the curriculum is interpreted, understood, manipulated, adapted and transformed by teachers in their interaction with students. Hence, what could be “seemingly straightforward policies (…) are often implemented very differently across localities, schools and classrooms” (Elmore and Sykes 1992, 186) as system (governance structures), school, community, teacher, and student factors pull teachers in often conflicting directions. Teachers’ enactment of the mathematics curriculum in elementary schools is circumscribed by these factors, and therefore may not correspond to what has been intended.

This leads to two considerations of interest to curriculum enactment research: first, teachers should have the necessary tools and guidance to be in a position to make adequate decisions as they enact curricular policy, and second, because local context and teachers’ histories and characteristics differ, the impact of one or similar policy structures will vary. These considerations motivate key questions for this study:

- Do similar policy structures have similar effects on teachers’ instruction, particularly in relation to their correspondence to the intended curriculum?
- Is this correspondence associated with higher academic achievement?
Finally, this review evinces the dearth of studies that focus on identifying patterns of the mathematics curriculum in low performing countries that consider, both, intentions and enactment, as well as the correspondence between the two. Similarly, the association of many of the factors discussed to the enacted curriculum is at best only analytically considered for low performing countries. And albeit these analyses suggest possibilities for patterns in low performing countries, they do not lead to definite hypotheses. Nonetheless, possible hypotheses are advanced. First, it is hypothesized that high performing nations enact a more challenging mathematics curriculum. Second, it is assumed that the degree to which teachers enact a curriculum in line with curricular policy varies across contexts and that such enactment varies according to teachers’ interaction with curriculum intentions, policy instruments and their own knowledge, experience, and beliefs. However, it is suggested that the mathematics taught and how it is taught responds to a higher degree to teacher factors. Variation in the degree to which each of the factors is associated with the enactment of the curriculum is expected across and within each group of countries - low and high performing.
Chapter 3. METHODOLOGY

3.1. Introduction

This chapter presents the data source, the research design and the methodology chosen to answer the research questions. Based on the relationships identified in the literature, the methodology seeks to make a comprehensive analysis of the enacted curriculum and explore the possible influence on it of various factors, using a comparative lens.

As stated in Chapter 1, the research questions that guide this study are:

1. Concerning curriculum policy enacted in classrooms:
   a. What is the mathematics curriculum taught in high and low achieving countries in eighth grade?
   b. How does the enacted mathematics curriculum of high and low performing countries differ?
   c. What is the relationship between the enacted curriculum and the intended curriculum in high and low achieving countries?

2. Concerning the mathematics enacted curriculum and different types of factors:
   d. Do policy instruments influence teachers’ decisions in the enactment of the mathematics curriculum in high and low achieving countries?
   e. Do teacher factors influence teachers’ decisions in the enactment of the mathematics curriculum in high and low achieving countries?
   f. Do factors impinging upon teachers’ decisions in the enactment of the mathematics curriculum differ between or across low and high performing countries?

The construct of Opportunity to Learn described in the literature is used in the operationalization of the enacted curriculum. OTL and elements that frame it are analyzed using
a quantitative methodology. The review of literature showed that both quantitative and
qualitative approaches have been used to study the enacted curriculum and its relation to system
factors and individual factors. However, while system factors have been examined mostly
quantitatively, individual factors have been mostly observed through qualitative methods. Given
the scope of this study – far reaching in regard to the number of contexts examined – a
quantitative methodology is chosen as the more appropriate to respond to the research questions.
I also take advantage of the opportunity to analyze an important data set – the TIMSS – from a
perspective rarely followed in the literature: pursuing research questions primarily focused on
low-achieving countries, where the profiles of high-achieving countries serve as comparative
benchmarks.

I advance the following possible hypotheses from the concepts and relationships found in
the literature.

1. Concerning curriculum policy enacted in classrooms:
   - The enacted curriculum differs between high and low performing countries overall. It is
     hypothesized that eighth grade teachers in high performing countries teach more
     advanced content topics to a greater extent, and use more challenging performance
     expectations and instructional strategies than teachers in low performing countries.
   - High performing countries have closer correspondence between the enacted and intended
     curriculum. However, variation in the degree of correspondence is presumed to exist
     within both groups of countries. It is also expected that the intended curriculum of the
     two groups converges, in part due to the general framework that is used to examine the
     mathematics curriculum and OTL.\textsuperscript{33}

\textsuperscript{33} A more detailed curricular framework would include the subtopics within each subject area – number,
geometry, and data -, and the inclusion of these sub-topics could vary in breath and level of difficulty.
2. Concerning the mathematics enacted curriculum and different types of factors:
   - Policy instruments are associated with teachers’ enacting of the mathematics curriculum in both high and low achieving countries, although some policy instruments are hypothesized to have a stronger effect in one group or the other.
   - Variation of teacher individual factors is associated with variation in teachers’ enacting of the mathematics curriculum in both high and low achieving countries.

3.2. Data Source

   The study of policy enactment proposed depends on comprehensive data on the curriculum, both intended and enacted, and on system- and teacher-related factors for a wide set of countries. The data gathered by the Trends in International Mathematics and Science Study (TIMSS) provides the best opportunity to test these hypotheses on a global scale. TIMSS assesses students’ learning of mathematics and science at the fourth and eighth grade levels based on a curricular framework established by an international community of experts.

   According to TIMSS, the aim of the study is to improve student learning. Thus, linking student achievement to school practices and educational policies is essential. More specifically, in the case of curriculum and achievement, the study advocates comparisons of achievement that take into account the curriculum that students have been given the opportunity to learn. For this, curriculum data are gathered from each country.

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34 TIMSS is carried out by the International Association for the Evaluation of Educational Achievement (IEA). For the last 20 years, TIMSS has measured student achievement in relation to opportunity learn. Conducted on a regular 4 year cycle, TIMSS has been particularly important for curriculum research given that it assesses the learned curriculum in mathematics and science by 4th and 8th graders across more than 50 countries.

   The study of the curriculum through TIMSS is facilitated due to the study’s collection of curriculum data from national curriculum experts, teachers and schools. Teacher questionnaires gather information in regards to their instruction, including content, focus, and perceptions, providing an opportunity to study the implemented curriculum.
The students assessed by TIMSS 2011 are part of nationally representative random samples of students selected from the target population in each country (Mullis et al. 2012) - students enrolled in the grade that represents 4 and 8 years of schooling using UNESCOs International Standard Classification of Education (ISCED\textsuperscript{35}).\textsuperscript{36} The sampling design used in the study is a two-stage stratified cluster sample design: first, a sample of schools was selected in each country with probabilities proportional to their size, followed by a selection of one or more intact classrooms within the sampled schools. School stratification was used in the sampling of schools. The number of participating schools per country or benchmarking territory for the eighth grade mathematics assessment ranges from 43 (Colorado, United States) to 501 (United States).

The curriculum and teacher questionnaires gather data on the curriculum, national policies, teacher characteristics and contextual factors. Experts respond to one curriculum questionnaire per country providing information at the system level, including policies, methods, and curricular content matter. Teachers surveyed those who teach mathematics to TIMSS eighth grade sampled students and therefore do not constitute a representative sample. These data include teacher background information, teacher perceptions on several school issues, content matter coverage, and the activities they carry out in their classrooms.

3.3. Model

The model in Figure 3.1 shows the interrelationships among the concepts raised in the research questions and discussed in the literature review. It draws on previous analyses of OTL

\footnote{35 \url{http://www.uis.unesco.org/Education/ISCEDMappings/Pages/default.aspx}}

\footnote{36 In this (2011) application, three countries – where the assessment was too difficult to 4th grade students – applied the 4th grade assessment to 6th grade students: Botswana, Honduras and Yemen.}
and the curriculum (Valverde et al. 2002; Porter and Gamoran 2002). The model depicts two types of elements: 1) the curriculum, defined at the system level and at the classroom level as students’ opportunities to learn and 2) the factors hypothesized, based on the literature, as influencing factors of how teachers define students’ OTL through their decisions. The latter include two categories of factors. The first are policy instruments, assumed to be part of a curricular governance system. The second type of factors refers to teachers’ individual characteristics. These individual factors are influenced, in turn, by the policy instruments.

Figure 3.1: Conceptual model
*Source:* author’s elaboration drawing from the literature review.

The arrow between the intended and the enacted curriculum represents perhaps the main direct influence on teachers’ instructional decisions. As the literature indicates, these two levels of the curriculum do not entirely correspond, but their degree of correspondence is associated with the degree to which curricular attainment goals are reached. The intended curriculum has an
indirect influence on teachers’ decisions through the policy instruments, when all of these converge towards the same objectives. The influence of the curriculum on teachers, including their subject matter knowledge or understanding of curricular goals, is mediated through the policy instruments used by the system. However, in this study, only the direct associations of subject matter content knowledge with teachers’ instructional decisions will be explored.

3.4. Countries

As discussed in the two prior chapters, due to globalization and the associated preponderance of international benchmarking practices, policies in education systems across the world are moving towards convergence. The adoption of “best” policy solutions, considered so by existing in “top ranking” countries or being promoted by international organizations37, is the main mechanism of this trend. One of the things this study seeks to highlight is the extent to which the mathematics curriculum and policies converge over high and low achieving countries. To this end, countries were classified according to their performance in TIMSS 2011, mainly, but also considering their consistent low or high performance by looking at TIMSS 2007 and 2003.

Table 3.1 shows the countries that participated in TIMSS 2011 as well as their scores for 2011, TIMSS 2007 and 2003, in the case they participated in these applications. Countries were first selected for the study if they participated in at least two of the studies (except for Finland) and obtained in these participations an average significantly above or below the international average. It is noted that participation was more consistent across high performing countries, of

37 Specifically, the Organization for Economic Co-operation and Development promotes particular policy agendas especially for developing or poor performing countries in international assessments. It has worked through agreements to assess countries as they design and carry out education reform. In addition, the World Bank has often tied financial support to countries to their following specific agendas.
which the vast majority participated in all three applications (except for Finland). Participation of low performing countries, on the other hand, is less consistent; four out of ten countries participated twice while the rest participated all three occasions. The United States, whose average performance is slightly above the TIMSS average, is included as a case of interest in the high performing group. In addition, Finland is included in the high performing group in spite of having only participated in 2011 since it stands out for its consistently high performance in the PISA assessment. Although variation in relation to the world region in the low performing group has been possible, the same is not the case for the high performing group of countries. Most of the countries in this group belong to the Asia-Pacific rim.

Table 3.1: Countries participating in TIMSS 2011

<table>
<thead>
<tr>
<th>Country</th>
<th>Average 2011</th>
<th>TIMSS 2007</th>
<th>TIMSS 2003</th>
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<td>Korea, Rep. of</td>
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<td>Singapore</td>
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<td>International Average</td>
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</tr>
<tr>
<td>Tunisia</td>
<td>425</td>
<td>420</td>
<td>410</td>
</tr>
<tr>
<td>Chile</td>
<td>416</td>
<td></td>
<td>387</td>
</tr>
<tr>
<td>Iran, Islamic Rep. of</td>
<td>415</td>
<td>403</td>
<td>411</td>
</tr>
<tr>
<td>Qatar</td>
<td>410</td>
<td>307</td>
<td></td>
</tr>
<tr>
<td>Bahrain</td>
<td>409</td>
<td>398</td>
<td>401</td>
</tr>
<tr>
<td>Jordan</td>
<td>406</td>
<td>427</td>
<td>424</td>
</tr>
<tr>
<td>Palestinian Nat’l Auth.</td>
<td>404</td>
<td>367</td>
<td>390</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>394</td>
<td>329</td>
<td>332</td>
</tr>
<tr>
<td>Indonesia</td>
<td>386</td>
<td>397</td>
<td>411</td>
</tr>
<tr>
<td>Syrian Arab Republic</td>
<td>380</td>
<td>395</td>
<td></td>
</tr>
<tr>
<td>Morocco</td>
<td>371</td>
<td>381</td>
<td>387</td>
</tr>
<tr>
<td>Oman</td>
<td>366</td>
<td>372</td>
<td></td>
</tr>
<tr>
<td>Ghana</td>
<td>331</td>
<td>309</td>
<td>276</td>
</tr>
</tbody>
</table>

Source: TIMSS 2011 assessment.

The second criterion used to typify countries as high or low performers is based on the mean national mathematics scores in TIMSS 2011. Countries whose mean score is significantly above the TIMSS scale center point (500 points) are categorized as high performing, while countries with mean scores significantly below the center point of the scale are categorized as low performing.\(^{38}\) Of the 45 countries and 14 benchmarking territories that participated in the TIMSS 2011 eighth grade assessment, 18 countries were selected. These countries are listed in Tables 3.1 and 3.2, along with their mean national scores and standard errors.

\(^{38}\) The center point is used as a point of reference since it remains constant from assessment to assessment, allowing comparisons in time.
The constructs and relationships in the model are analyzed across the two sets of countries, and then compared between and within groups. Comparative research helps researchers understand educational issues by identifying similarities and differences and seeking their underlying causes (Crossley and Watson 2003). Thus, the analysis proposed intends to identify, first, the variability of variables across countries that produce similar results, and second, the impact of system level and individual teacher factors on these variables. In other words, this study seeks to identify differences and similarities in the OTL provided to students in high achieving and low achieving countries, and the association that exists between specific policies and teacher factors, on one hand, and OTL, on the other.

Table 3.1: Top performing countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td>613 (2.9)</td>
</tr>
<tr>
<td>Singapore</td>
<td>611 (3.8)</td>
</tr>
<tr>
<td>Chinese Taipei</td>
<td>609 (3.2)</td>
</tr>
<tr>
<td>Hong Kong SAR</td>
<td>586 (3.8)</td>
</tr>
<tr>
<td>Japan</td>
<td>570 (2.6)</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>539 (3.6)</td>
</tr>
<tr>
<td>Finland</td>
<td>514 (2.5)</td>
</tr>
<tr>
<td>United States</td>
<td>509 (2.6)</td>
</tr>
</tbody>
</table>

Source: TIMSS 2011 assessment.
Note: 2 National Defined Population covers 90% to 95% of National Target Population.

Table 3.2: Low performing countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ukraine</td>
<td>479 (3.9)</td>
</tr>
<tr>
<td>Norway</td>
<td>475 (2.4)</td>
</tr>
<tr>
<td>Romania</td>
<td>458 (4.0)</td>
</tr>
<tr>
<td>Turkey</td>
<td>452 (3.9)</td>
</tr>
<tr>
<td>Lebanon</td>
<td>449 (3.7)</td>
</tr>
<tr>
<td>Thailand</td>
<td>427 (4.3)</td>
</tr>
<tr>
<td>Chile</td>
<td>416 (2.6)</td>
</tr>
<tr>
<td>Iran, Islamic Republic of</td>
<td>415 (4.3)</td>
</tr>
<tr>
<td>Country</td>
<td>Score (Average)</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------</td>
</tr>
<tr>
<td>Indonesia</td>
<td>386 (4.3)†</td>
</tr>
<tr>
<td>Morocco</td>
<td>371 (2.0)ψ</td>
</tr>
</tbody>
</table>

*Source: TIMSS 2011 assessment.*

Notes: 2 National Defined Population covers 90% to 95% of National Target Population.

† There are reservations about reliability of average achievement because the percentage of students with achievement too low for estimation does not exceed 25%, but it exceeds 15%.

ψ Average achievement not reliably measured because the percentage of students with achievement too low for estimation exceeds 25%.

Given that the sample of countries used for the study is not a random sample, results are only applicable to the countries analyzed. However, the findings can have some relevance for other consistently high and low performing countries.

### 3.5. Operationalization of the constructs and variables

The following paragraphs explain the operationalization of the constructs and the indicators used for the study. The mathematics curriculum is defined using four components: content, performance expectations, instructional strategies, and instructional time. Content refers to the specific mathematics content topics, each belonging to an area of mathematics knowledge (number, geometry and data); performance expectations refers to cognitive or thinking processes or what the students are expected to (exposed to or actually) do with the content taught (Schmidt et al. 1997), such as memorize, communicate, or reason abstractly; instructional strategies are the pedagogical techniques used in the teaching of content and performance expectations, such as lecture or solving problems with the participation of students; instructional time is the time meant to be (or actually) dedicated to the mathematics curriculum.
3.5.1. Opportunity to Learn

For this study, OTL is limited to the mathematics curriculum that students are exposed to, the type of activities through which they are exposed and the time of exposure, according to teacher reports. Although some authors refer to OTL more broadly, including teacher, school and larger contextual variables (Cawthon et al. 2012; Wang 1998), this study limits the scope of OTL to that which occurs during the teaching and learning process in the classroom.

Both OTL mathematics in the 8th grade and the mathematics curricular intentions are derived from several items in the 2011 TIMSS questionnaires. The teacher questionnaire is used to operationalize the enacted curriculum, or OTL at the level of instruction, and the data from the curriculum questionnaire are used to determine intended OTL. The operationalization of each of these variables follows.

*Enacted or implemented curriculum or OTL*

As stated above, the enacted curriculum is comprised of the content matter, performance expectations, instructional strategies and instructional time that the students assessed were exposed to during the year.

**Content matter.** Three variables constitute OTL content matter and these are derived from 19 items responded by teachers on the same number of content topics established in the mathematics curricular framework (see question ET1 in Appendix A). Four subject areas are covered in the framework, which determine the 4 variables for content topics: 1) number, 2) algebra, 3) geometry, and 4) data and chance. The items used to create these variables are turned first into indicators of whether a topic is “taught mostly before this year or “taught this year” = 1 or it has “not yet been taught or was just introduced” = 0. Here, two indicators of OTL content
matter are determined: 1) the average percentage of students taught the topics in each of the subject areas at the country level, estimated with the percentage of students taught each of the topics per country, and then averaging these percentages for each of the four subject areas, and 2) the extent to which each teacher covers the topics in each subject area, based on the total number of topics per subject area (number = 5, algebra = 5, geometry = 6, and data and chance = 3). The values for this variable are based on the percentage of topics actually covered by the teacher, as follows: 0-25% = 1, 26-50% = 2, 51-75% = 3, and 76 – 100% = 4. The first indicator for the 4 variables serves to determine convergence between the intended and the enacted curriculum focusing on the country as the unit of analysis. The second indicator is assessed at the teacher/classroom level and it is used to explore the association of OTL and each of the factors considered in this study.

**Performance expectations.** Six items in the teacher questionnaire report on the frequency of activities that indicate teachers’ emphasis on specific performance expectations (see ET2, b, f, g, h, i, and j in Appendix A). Based on the literature, two variables are proposed from these six items to define low and high cognitively demanding performance expectations. The first two (b and f) are proposed as low cognitively demanding (LDPE) while the last four (g, h, i and j) are considered examples of highly demanding performance expectations (HDPE). For each item in the questionnaire, the measure for teachers’ emphasis on each of these activities is the estimated number of lessons in which they ask students to perform them (1 = never, 2 = some lessons, 3 = about half the lessons, and 4 = every or almost every lesson). For the two variables averages across the items are converted into the same scale as follows: 1 thru 1.699=1, never; 1.7 thru 2.499=2, some lessons; 2.5 thru 3.299=3, about half of the lessons; 3.3 thru 4 = 4, every or
almost every lesson. In addition, to compare PE enacted to those intended, 4 items were matched to the specific PE reported by curriculum experts in each country or benchmarking territory.

**Instructional strategies.** These variables are derived from a set of 7 items (see ET3, a, c, e, and ET4, a, b, c, and f in Appendix A) that request teachers to provide the frequency with which they follow certain teaching strategies. Like performance expectations, the classification of these items is proposed to define two variables: low and highly challenging instructional strategies. The first 4 items are classified as low cognitively challenging instructional strategies (LCIS), while the latter three are classified as high cognitively challenging instructional strategies (HCIS). The values for the two variables are equal to those of the performance expectations variables. Both performance expectations and instructional strategies are analyzed at the classroom/teacher level while percentages of frequencies with which each type of performance expectation is practiced by teachers at the country/territory level is used to compare the intended and enacted curriculum.

**Instructional time.** Two types of variables are created for IT. The first - yearly number of hours of mathematics instruction - is derived from two items in the school questionnaire and one item in the teacher questionnaire. The first two items gather information on the days per year that the school is open for instruction (ES6) and the days per calendar week that the school is open for instruction (ES8). For the third item, teachers indicated the number of hours and minutes per week that they taught mathematics to 8th grade students (ET5). The resulting variable is measured in the yearly number of hours of mathematics IT.

The second type of variable is measured in the percentage of time that a teacher spends on each of the 3 mathematics subject areas, and this is provided in the teacher questionnaire (ET9). Four variables are created, one for each subject area. These variables are analyzed
looking at the teacher/classroom as the unit of analysis in general and at the country/territory in order to compare intentions and enactment.

*Intended OTL*

The variables for curricular intentions are in exact correspondence with the content items in the curriculum questionnaire. Thus, the same subject areas – number, algebra, geometry, and data and chance – define each of the variables.

**Content matter.** Content matter in the intended curriculum is derived from 19 items (EC10 in Appendix A) in the curriculum questionnaire that are part of the mathematics TIMSS curricular framework. These topics are grouped into 4 specific subject areas: number (5 topics), algebra (5), geometry (6) and data and chance (3) topics. These groups determine the 4 variables for content matter. The inclusion of each content topic in the country’s intended curriculum is indicated with the estimated number of students that are intended to be given the opportunity to learn it. The response options provided in the questionnaire are turned into the following percentages: 1) all or almost all = 90%, 2) only the more able = 10%, and 3) not included in the curriculum through 8th grade = 0. To determine a value of the four variables, the average percentage of students intended to be taught all topics of each subject area is calculated per country or territory and for each group of countries.

**Performance expectations.** The intended performance expectations are measured through 3 items from the curriculum questionnaire that indicate the emphasis prescribed for each of the PE from less to more demanding (IC11, a, b and c in Appendix A). Based on the literature, these three items are classified into 2 categories: low cognitively demanding performance expectations (LDPE: a) and highly cognitively demanding performance expectations (HDPE: b
and c). The items use a 1-4 point scale to indicate the degree of emphasis on each kind of activity, where none = 1, very little = 2, some = 3 and a lot = 4. To obtain the value of the two new variables (intended LDPE and HDPE), the average is calculated for the second variable and the values are converted to the 1-4 scale as follows: 1 thru 1.699=1, never; 1.7 thru 2.499=2, some lessons; 2.5 thru 3.299=3, about half of the lessons; 3.3 thru 4 = 4, every or almost every lesson. These values are also used for the first variable - LDPE. Both variables are assessed at the country or territory level.

**Instructional time.** The variable for IT is measured through one item in the curriculum questionnaire (see EC13 in Appendix A). This is a continuous variable expressed in percentage points indicating the relative amount of the “total instructional time to be devoted to mathematics instruction at the eighth grade of elementary school”.

### 3.5.2. The policy instruments and curricular governance system

The factors analyzed as potentially influencing of teachers’ enacting of the curriculum are situated at the classroom/teacher level and therefore are operationalized through teacher data. Although some of these factors, such as teacher certification and teacher professional development, are policies established at the system level, the intent here is to determine whether these policies, when actually followed by teachers are associated with the enactment of the curriculum. Only one element is examined at the system level – evaluation of curriculum implementation –, for which data is only provided in the curriculum questionnaire.

To operationalize the *evaluation of curriculum implementation*, I use 5 items in the curriculum questionnaire that report whether a policy instrument exists for this purpose (see FC13 a - e in Appendix A). The variable measure indicates the emphasis placed on evaluation
through the use of policy instruments. The values, then, range from 0, meaning that no instruments are used, to 5, meaning that 5 instruments are used, at least (1 = one instrument is used, 2 = 2 instruments are used, and so forth).

**Teacher professional development.** Six PD variables are used to examine PD in relation to OTL, each of these corresponding to one item in the teacher questionnaire (considered at the teacher/classroom level; see FT16 a-g in Appendix A). These items report whether a teacher has participated in the following: PD for mathematics content; PD for mathematics pedagogy/instruction; PD for mathematics curriculum; PD for improving students’ critical thinking or problem-solving skills; PD for mathematics assessment; and PD for addressing individual students’ needs. Each type of PD, as a variable, is examined in relation to the elements of OTL.

**Textbook use.** The variable is included in the study as a mediator between curricular policy and instruction to which research attributes a strong impact on achievement, especially for mathematics (Schmidt et al. 2001; Valverde et al. 2002). The one variable that defines textbook use, considered at the teacher/classroom level, derives from 1 item in the teacher questionnaire (see FT17 IN Appendix A) and it is turned into a dummy variable to indicate whether teachers use textbooks as a primary basis for lessons.

**Teacher collaboration.** The frequency with which teachers interact with other teachers in specific ways is used to determine teacher collaboration, and it is defined at the teacher/classroom level. Five items in the teacher questionnaire are used to derive this variable (see FT18 IN Appendix A), and these report on the frequency with which teachers carry out activities that involve interaction and exchanges with other teachers. Values are averaged across the 5 items and the following new values given: 1 = Never or Almost Never = Average is less
than or equal to 1.4, 2 = 2 or 3 Times per Month = Average is greater than 1.4 and less than or
equal to 2.4, and 3 = At Least Weekly = Average is more than 2.4.

3.5.3. Teacher factors

Three teacher factors are measured and examined in relation to the enacted curriculum;
these are: years of experience, teacher education, and perceived subject matter knowledge.

Years of experience. The number of years that teachers have been teaching is taken from
item FT19 in Appendix A. The variable is defined at the teachers/classroom level.

Teacher education. This variable informs of teachers’ emphasis on mathematics or
pedagogical education or both, and it is derived from one item in the teacher questionnaire (see
FT14 in Appendix A). The following values are given to the teacher education variable:
1=Major in Mathematics and Mathematics Education, 2=Major in Mathematics Education but
No Major in Mathematics, 3=Major in Mathematics but No Major in Mathematics Education,
4=All Other Majors (based on TIMSS Supplement 3). The unit of analysis for teacher education
is the teacher/classroom.

Perceived subject matter knowledge. Three variables define teachers’ perceived subject
matter knowledge. These are derived from 19 items (see FT21 in Appendix A) in which teachers
report how well prepared they feel to teach the 19 topics in the framework. The response options
in each item (very well prepared = 1, somewhat prepared = 2, and not well prepared = 3) for each
of the four subject areas are averaged. The average is recoded into the following values: a) 1 =
not well prepared = average 2.4 – 3, b) 2 = somewhat prepared = average 1.7 – 2.3, and c) 3 =
very well prepared = average 1 – 1.6. Subject matter knowledge is assessed at the teacher level.
3.5.4. School context

Teachers’ collective perception about their teaching and learning community is explored through two variables: teachers’ understanding of curricular goals and teachers’ expectations for students’ learning.

**Teachers’ understanding of curricular goals.** One item in the teacher questionnaire corresponds to this variable. It reports how teachers perceive that other teachers in their school understand curricular goals (see FT20 in Appendix A). It is measured on a 0-5 scale, 0 indicating very low understanding and 5 indicating very high understanding.

**Teachers’ expectations for students learning.** The variable is derived from an item in the teacher questionnaire that requests teachers’ perceptions about what teachers’ in their school expect of students’ achievement (see FT22 in Appendix A). It is measured on a 0-5 scale, 0 indicating very low expectations and 5 indicating very high expectations. Both variables are assessed at the school level.

<table>
<thead>
<tr>
<th>Construct/Latent Variable</th>
<th>Indicator</th>
<th>Variables/(scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTL</td>
<td>% of students for whom content matter (by mathematics subject area) is covered (country is the unit of analysis)</td>
<td>Number/Algebra/Geometry/Data and Chance coverage intended and enacted (continuous 0-100)</td>
</tr>
<tr>
<td></td>
<td>Extent of topic coverage by teacher</td>
<td>Number/Algebra/Geometry/Data and Chance area coverage per teacher (1=less topics covered – 4=the most topics covered)</td>
</tr>
<tr>
<td></td>
<td>Frequency with which performance expectations are employed by teachers (0-3)</td>
<td>High cognitively demanding performing expectations(HDPE) and Low cognitively demanding performance expectations (LDPE): ordinal (0 = never, 1 = some lessons, 2 = about half the lessons, and 3 = every)</td>
</tr>
<tr>
<td>Table Content</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Frequency with which instructional strategies are used by teachers</td>
<td>Highly challenging instructional strategies (HCIS) and Low challenging instructional strategies (LCIS): ordinal (0 = never, 1 = some lessons, 2 = about half the lessons, and 3 = every or almost every lesson)</td>
<td></td>
</tr>
<tr>
<td>Hours of instructional time</td>
<td>Instructional time: ratio (hours)</td>
<td></td>
</tr>
<tr>
<td>Percentage of instructional time prescribed for teaching mathematics</td>
<td>Instructional time prescribed for teaching mathematics</td>
<td></td>
</tr>
<tr>
<td>Emphasis on evaluation of curriculum implementation</td>
<td>Dichotomous variables (yes/no): visits by inspectors (supervision) - observations by principal or senior staff - teacher peer review - student achievement</td>
<td></td>
</tr>
<tr>
<td>Teacher preparation</td>
<td>Type of teacher education/certification, (categorical)</td>
<td></td>
</tr>
<tr>
<td>Teacher preparation in professional development activities (percentage)</td>
<td>Six dichotomous (yes/no) variables for each PD focused on the following areas: Mathematics content PD - Mathematics pedagogy/instruction - Mathematics curriculum - Improving students’ critical thinking or problem-solving skills - Mathematics assessment - Addressing students’ individual needs</td>
<td></td>
</tr>
<tr>
<td>Textbook use</td>
<td>Using the textbook as a main resource in class (percentage of teachers) Textbook use</td>
<td></td>
</tr>
<tr>
<td>Teacher collaboration</td>
<td>Teacher collaboration (ordinal: 1-3). Value given by the frequency of participation in the following: a) discussions about how to teach a topic b) work with other teachers to prepare</td>
<td></td>
</tr>
</tbody>
</table>

80
instructional materials, c) visit another teacher’s classroom to observe, and d) informal observations by another teacher.

<table>
<thead>
<tr>
<th>Experience</th>
<th>Years of experience</th>
<th>Experience: ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding of curricular goals</td>
<td>Degree of understanding of curricular goals</td>
<td>Understanding of curricular goals: ordinal (very low, low, medium, high, very high – 1-5)</td>
</tr>
<tr>
<td>Subject matter knowledge</td>
<td>Degree of perceived subject matter knowledge (preparedness to teach topics in each subject area).</td>
<td>Preparedness to teach number topics: ordinal (not well prepared, somewhat prepared, very well prepared, 1-3) Preparedness to teach algebra topics: ordinal (not well prepared, somewhat prepared, very well prepared) Preparedness to teach geometry topics: ordinal (not well prepared, somewhat prepared, very well prepared) Preparedness to teach data topics: ordinal (not well prepared, somewhat prepared, very well prepared)</td>
</tr>
<tr>
<td>Expectations for students learning</td>
<td>(Teachers’) Perceived level of expectations for students’ learning.</td>
<td>Expectations for students’ learning: ordinal (very low, low, medium, high, very high)</td>
</tr>
</tbody>
</table>

3.6. Data Analysis

The data is analyzed in two phases, in accordance with the research questions. For the first phase, exploratory data analyses are used to describe and evaluate variables and to identify the similarities and differences in OTL provided in the two groups of countries. Descriptive statistics, including univariate and bivariate analyses, are used to identify the intended curriculum and the enacted curriculum. In addition, the comparison of these two manifestations of OTL is made across and within countries to establish differences in the degree of correspondence between policy and instruction.
The second phase of this analysis intends to determine the association of policy instruments and teacher factors, on one hand, and teachers’ defining of students’ OTL through their enactment of the curriculum, on the other.

*OTL in high and low performing countries*

The first and second research questions require identifying OTL, or the enacted curriculum, in the two groups of countries. Content topics, performance expectations, instructional strategies and instructional time variables are estimated using descriptive statistics. Two measures are used to define content topics taught: the first, assessing OTL by focusing on the country or territory as the unit of analysis, provides the percentage of (sampled) students taught each of the content topics and an average across each subject area; the second measure indicates the extent to which teachers cover the topics in each of the four subject areas (at the classroom/teacher level). Means and measures of dispersion (e.g. range of variation) in each group of countries are estimated to characterize each group. In addition, while the first indicator is used primarily to compare the enacted to the intended curriculum using the country/territory as the unit of analysis, the second indicator – extent to which the topics in each subject area are covered by teachers – is used to examine content in relation to the other variables in the study using the teacher/classroom as the unit of analysis.

To compare the extent to which teachers in high and low performing countries cover the topics in each subject area as well as the frequencies for PE, I use cross-tabulations and Pearson’s chi-square test, focusing on the teacher/classroom as the unit of analysis. Between and within group, as well as within country differences are observed to identify patterns in content coverage and the use of PE. The IS variables are treated similarly. Frequencies in the use of high
and low challenging strategies are observed using cross tabulations, while Pearson’s chi-square test is used to compare the use of each type of instructional strategy between the two groups of countries and territories.

IT is measured in hours per week and yearly hours of mathematics instruction both at the country/territory level and at the teacher/classroom level. Means and measures of variation are estimated for each group and for each country. The percentage of time dedicated to each content topic is also estimated for the enacted curriculum at the teacher/classroom level. To compare IT across high and low performing groups, I apply t-tests, giving particular attention to measures of variation across groups.

Comparing the enacted and the intended curriculum

Responding to the third research question, the intended curriculum variables are compared to the enacted curriculum variables. Given that the intended curriculum (system) variables are at the country level, comparisons can only be descriptive. The percentages of students intended to be taught each content topic are compared to the actual percentages of students taught the content topics by country or territory and for the two groups. Similarly, the frequencies with which teachers employ each of the types of PE in the classroom are observed in relation to the intended emphasis meant at the national level (see IC11 in Appendix A). Specifically, the intended emphasis for each type of PE is contrasted to the percentage of teachers that more often emphasize that particular type of PE.

The degree of correspondence in IT— is examined comparing the percentage of total instructional time meant to be devoted to mathematics (see IC13 in Appendix A) to the equivalent mean percentage of time at the classroom level, given by school and teacher
responses (ES6 – ES8 in Appendix A). The difference between the percentage of time intended and enacted is calculated for each country and used to compare the two groups by looking at the means and the range of variation. I hypothesized that the difference between the two groups is minimum, with some variation across countries.

Exploring factors and relationships among variables

In order to compare curricular governance systems, a characterization is made of the policies used across the two groups, highlighting specific country cases. Using descriptive statistics, including univariate and bivariate analyses, the system and individual teacher factors that are considered in this study are explored to depict the characteristics of curricular governance systems in the selected countries, show similarities and differences among them, and help identify any patterns within each group of countries. To explore the association of policies, context and individual teacher factors, bivariate tests are applied for each factor with each of the 4 components of OTL. With this, I explore questions 2a and 2b of the study.

To examine the relationship between teacher professional development, on one side, and content topics (extent to which topics are taught for each subject area), PE, and instructional strategies, on the other, cross tabulations and chi-squared test are used.

To test the relationship between each of the following factors: teacher education, teacher collaboration, teachers subject matter knowledge, the use of textbooks with the elements of OTL, Pearson’s chi-square test is used for the case of content topics, PE and IS (categorical variables), while independent t-tests are used in the case of IT (the continuous variable). These bivariate tests employed in each of the two groups of countries are intended to help identify relationships between the factors and any of the components of OTL.
To compare content, PE and IS elements of OTL across the two groups of countries in relation to each of the factors, loglinear analysis were used for the categorical OTL variables (content topics, performance expectations, and instructional strategies. Loglinear analysis is a test (equivalent to chi-square) used for categorical data when there are more than two variables. The variable for high and low performing countries adds another level to the analysis of the association between factors and OTL.

In order to test the association of factors with instructional time, the Kruskal-Wallis test was performed along with the Mann-Whitney test to look at bivariate associations, given the non-normal distribution of the data for IT.

3.7. Summary

To capture the intended and enacted curriculum and establish the association of the latter to system and teacher factors, a quantitative methodology is applied. The data from the TIMSS 2011 study for eighth grade mathematics are used since it provides curriculum, system, and classroom level data across a wide set of nations. Two clusters of countries have been created to analyze the enacted curriculum and potentially influencing factors from a comparative perspective in relation to their national mean performance on TIMSS. Two phases are proposed for the data analysis. The first is an exploratory analysis using univariate analysis to examine OTL. The second set of analysis examines the association between these OTL variables and policy, context and individual teacher factors.
Chapter 4. OTL IN THE MATHEMATICS CURRICULUM

4.1. The enacted mathematics curriculum in high and low performing countries

4.1.1. Content coverage

Addressing the question about the mathematics curriculum enacted in low and high achieving countries, the first set of analyses explores one of the four elements of OTL analyzed in this study: mathematics content. The results presented here convey the content covered in classrooms within and across the low and high performing groups of countries and territories according to teachers’ reports. I expected to identify important differences between the two groups of countries in teachers’ coverage and considerable variation across countries or territories. Some differences were found between the two groups, but there were also important similarities for some topics.

Figure 4.1 shows the percentage of teachers in each group that reported coverage of each of the 19 mathematics content topics before or during 8th grade. These are grouped into the four mathematics content areas: number, algebra, geometry and data. Consistent with the findings in previous studies, number topics were extensively covered in basic education in both low and high performers. All five number topics in the analysis framework were covered by more than 90% of teachers in both groups of countries either before or during the 8th grade. Also, in both groups, the topic problem solving involving percent and proportions, involving more demanding performance expectations is the number topic reported as taught by the lowest percentage of teachers (93.7 and 95.6% for low and high performing, respectively), although it was still broadly covered. Overall, there were no important differences identified in the coverage of number topics between low and high performers. However, according to Pearson’s chi square
test the differences were significant for all content topics except for concepts and computing with decimals.\textsuperscript{39}

In contrast to number topics, differences in the extent to which algebra topics were covered in the low and high performing groups of countries or territories were noted in all five algebra topics. These differences were significant for all content areas except for simultaneous two variable equations.\textsuperscript{40} About 20\% more teachers reported the topic numeric, algebraic, and geometric patterns or sequences as taught in high performing countries or territories than those in low performing group; similarly, 4\% and 6\% more teachers in the high performing group reported the topics simple linear equations and inequalities and simplifying and evaluating algebraic expressions as taught, respectively; and 12.5\% more teachers in high performers reported the topics representation of functions as ordered pairs, tables, graphs, words, or equations as being taught during or before 8\textsuperscript{th} grade than teachers in low performers.

Nevertheless, the extent of coverage for most of the algebra topics was considerably less in both groups when compared to number topics. Simultaneous equations and representation of functions as ordered pairs, tables, graphs, words, or equations, considered the two of the more advanced algebra topics, were the two topics with the lowest coverage in both groups. Although coverage of algebra topics on average is lower, it varied across the five topics for both groups (LP range = 29.3; HP range = 33).

In geometry topics, considerable differences in coverage were found between low and high performers for four of the six topics. According to Pearson chi-square test, differences were

\textsuperscript{39} Computing, estimating, or approximating, x^2 \ (1) = 7.29, p < .05; concepts and computing with fractions: x^2 \ (1) = 3.98, p < .05; representing, comparing, ordering and comparing: x^2 \ (1) = 4.45, p < .05; problem solving – percentages and proportions: x^2 \ (1) = 7.91, p < .05.

\textsuperscript{40} Numeric, algebraic, and geometric patterns: x^2 \ (1) = 163.66, p < .001; simplifying and evaluating algebraic expressions: x^2 \ (1) = 45.52, p < .001; simple linear equations and inequalities: x^2 \ (1) = 13.52, p < .001; representation of functions: x^2 \ (1) = 77.77, p < .001.
significant for all of these topics\(^{41}\) except geometric properties of angles and geometric shapes, which was widely covered in both groups (by above 95% of teachers). The topic using appropriate measurement formulas for perimeters, circumferences, areas, surface areas, and volumes was covered to a similar extent in the two groups – by about 80% of teachers – although differences were significant ($x^2 (1) = 10.93, p < .05$). For the rest of the geometry topics, from about 6 to 20% more teachers in the high performing group reported coverage than teachers in the low performing group. Relationship between three-dimensional shapes and their two-dimensional representations and translation, reflection, and rotation, the two more advanced of the geometry topics in the framework, were the two least covered geometry topics in both groups of countries or territories.

Geometry topics were also covered less extensively than number topics through the 8\(^{th}\) grade in both groups of countries/territories, and on average to a similar extent as algebra topics. Also, as is the case of the latter, coverage varied across topics (LP range = 45.8; HP range = 39.2). On average, 71% and 70% of teachers in the low performing group reported covering all algebra topics and geometry topics, respectively, while in the high performing group the corresponding percentages were 80% and 78%. As hypothesized, in high performing countries or territories algebra and geometry topics were covered more extensively than in low performers; however, the difference was not as important as was expected.

The reported coverage of the three data topics informs of few differences between low and high performers. Only for the third data topic – judging, predicting, and determining the chances of possible outcomes, the more advanced of the three, were differences between the two

\(^{41}\) Congruent figures and similar triangles: $x^2 (1) = 68.01$ $p < .001$; relationship between three-dimensional shapes and their two-dimensional representations: $x^2 (1) = 14.95$, $p < .001$; using measurement formulas: $x^2 (1) = 10.93$, $p < .05$; points on a Cartesian plane: $x^2 (1) = 173.26$, $p < .001$; translation, reflection and rotation: $x^2 (1) = 159.01$, $p < .001$. 

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groups statistically significant $\chi^2 (1) = 40.75$, $p < .001$; 10% more teachers in the high performing group reported it as taught before or during 8th grade than teachers in the low performing group. It is also the data topic that was reported as less widely covered in both groups (by half and less than half of teachers). In comparison to the other three mathematics content areas, data topics were covered less broadly in both groups.

Within content areas, differences in topic coverage were also identified in both groups. In low performing countries, only 2 of the 5 algebra topics were reported as covered by more than 80% of the teachers while other 3 topics were reported as covered by less than 65% of teachers. In the high performing group, 3 of these algebra topics were reported as covered by 80% or more teachers while the other two were reported as covered by 61 and 76% of teachers.

In the case of geometry topics, in the low performing group only one of the 6 topics, considered the least complex, was reported as taught by more than 95% of the teachers during or before 8th grade, while the others were reported as taught by 84% of teachers or less. In the high performing group, 2 geometry topics were taught during or before 8th grade according to the vast majority – above 90% –, while other 2 had close to 80% reported coverage.

In general, number topics appeared to be covered widely in the low and high performing group before or during 8th grade. In the case of algebra, geometry, and data topics, there was variation in coverage for each content area across the two groups of countries or territories. More advanced topics were covered less widely. For these three content areas, lower coverage was reported by teachers in the low performing group than across high performers. Nevertheless, differences between low and high performers across topics in terms of the OTL mathematics through the 8th grade were smaller than expected. Only in five of the 19 content topics was this difference above 10% of teachers, but none of these were beyond 20%. And in 7 of these 19
topic differences are considerably small, in 5 of them not being significant. These differences in coverage among content areas could be indicative of differences in curricular intentions across groups.

Overall, the analysis of the enacted mathematics curriculum did not portray strong differences in terms of content topic coverage between low and high performers, as had been expected given the association between high achievement and being exposed to more challenging content topics established in previous studies (see Gamoran et al. 1997; Porter 1998; Schmidt et al. 2001, 2002; Valverde 2004; Valverde and Naslund-Hadley 2010; Valverde and Schmidt 2000). It seems, then, that it is not the exclusion of these topics from the curriculum in low performing countries that determines the lower achievement, so much as it may be the depth to which topics are covered.

4.1.2. Content topics covered across countries before and during 8th grade

Figure 4.2 shows the percentage of teachers that reported coverage of content topics during or before 8th grade and only during 8th grade by country. These percentages reflect the variation found in the total group percentages presented above: number topics were broadly covered across all countries, while the extent of coverage for topics in the other three content areas varied between groups and across countries or territories.

Reported coverage of content topics only during the 8th grade provided some indication of the extent to which topics may have been consistently covered throughout several grades, the breadth of content topics covered during one grade, and whether more advanced topics were introduced at this point or in prior grades. As expected, the findings indicate that coverage of 8th grade mathematics varied across countries, while some differences are noted between the groups.
Both, coverage prior to and during only 8th grade for each content area, are discussed in the following paragraphs.

Teachers’ reports of content coverage during or before 8th grade are consistent with findings in the literature (Baker et al. 2010; Schmidt et al. 2001), which identify that arithmetic topics dominate the primary school mathematics curriculum. They also confirm the relatively recent inclusion earlier in the schooling progression of geometry, algebra, and data topics found in these previous studies.

Number topics

Number topics, not surprisingly, were reported as covered extensively across all countries in the two groups by the 8th grade, with the exception of Norway,42 and Lebanon.43 In the high performing countries or territories, all number topics were reported as covered by the vast majority of teachers before or during 8th grade (above 96%), with the exception of Finland, where only 71.5% of teachers reported covering before or during 8th grade problem solving involving percents and proportions – considered one of the more advanced of the number topics.

In contrast, coverage of number topics specifically during the 8th grade was reported considerably less for both groups and for most topics, a finding that contrasts with that of Schmidt and colleagues (2001), in which fractions and number theory were among the most widely implemented topics during 8th grade, even when these were not emphasized in content standards. This difference found in the emphasis made on number topics during the 8th grade portrays a change in the enacted curriculum over this period; teachers as enactors appear to be

42 A lower number of teachers in Norway reported covering one of these number topics before or during 8th grade (75% for problem solving involving percents and proportions).

43 Problem solving involving percents and proportions was reported as covered by 82% of Lebanese teachers.
moving in the direction of curricular policy change, something that neo-institutionalists would argue as part of a larger worldwide phenomenon driven by transnational forces (McEneaney and Meyer, 2000), in this case likely the beliefs about the importance of mathematics for economic growth.

However, as expected, differences are noted between low and high performers. First, differences between the two groups in coverage of each of the number topics mostly during the 8th grade were statistically significant. Moreover, while, the vast majority of teachers in high performing countries or territories reported number topics as covered before the 8th grade, a considerable percentage of teachers (from about a third to two thirds) in half of the low performers (Chile, Lebanon, Morocco, Norway, and Thailand) reported covering number topics during the 8th grade. In Norway, for instance, more than 50% of teachers reported having taught all 5 number topics mostly during grade 8.

On average across number topics, 22.8% of teachers reported covering these mostly during 8th grade in low performing countries, while across high performing countries the reported coverage is 12%. These findings were expected, given the many factors that disproportionately affect teachers’ ability to enact the curriculum in developing countries, several of which are low performing. However, they highlight an important element of the enacted curriculum in low performers: a continued emphasis on topics that have presumably been extensively covered in previous grades, a finding that Schmidt and colleagues pointed out in their study in 2001. This finding is examined in sections below.

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44 Pearson chi-square test results for the following topics: computing, estimating, or approximating - $x^2 (2) = 26.41, p < .001$; concepts and computing with fractions – $x^2 (2) = 215.13, p < .001$; concepts and computing with decimals – $x^2 (2) = 161.15, p < .001$; representing, comparing, ordering and computing with integers - $x^2 (2) = 151.38, p < .001$; problem solving with percents and proportions – $x^2 (2) = 27.35, p < .001$.

45 Finland was an exception in the case of problem solving involving percent and proportions, for which reports indicated that nearly 66% of teachers cover the topic during 8th grade.
Coverage of algebra topics before or during 8th grade by country or territory was consistent with the two groups’ general findings. Overall, coverage was lower for most algebra topics than that reported for number topics in most countries, low and high performing. However, there was considerable variation across countries within both groups; that is, no clear patterns were identified that could be associated with higher performance. In low performing Norway, for example, teachers reported low coverage in all five algebra content topics either before or during 8th grade.\textsuperscript{46} Low performing Romania’s teachers, on the other hand, covered all topics for most students (86\% minimum and maximum of 100\%).

There is also wide variation in the extent to which any one of the algebra topics was covered across countries. Some topics were covered broadly in countries within groups while others were minimally covered. Across all low performing countries, no one topic was reported as covered consistently by most teachers. For example, \textit{Simultaneous (two variables) equations}, one of the more challenging algebra topics, was reported covered by more than 90\% of teachers in 5 of 10 low performing countries and by less than a third of teachers in the other 5 low performers.

Unexpectedly, in high performers, coverage of all 5 algebra topics during or before 8th grade also varied, although to a lower extent than in low performers. For instance, in Chinese Taipei and Singapore, all algebra topics were reported covered by the 8th grade by over 85\% and 90\% of teachers, respectively. In Finland and Slovenia, however, some topics were reported covered by less than 15\% of teachers.

\textsuperscript{46} As low as 1\% of teachers reported covering \textit{simultaneous equations} and as high as 56.7\% reported covering \textit{simplifying and evaluating algebraic expressions}.
In contrast to the low performing group, some algebra topics seem to have been consistently taught by most teachers across all high performing countries or territories, specifically *simplifying and evaluating algebraic expressions* and *simple linear equations and inequalities*. Interestingly *equations and formulas* was the topic most emphasized in the study by Schmidt and colleagues (2001) across TIMSS participating countries. However, some topics were minimally taught in one country while extensively taught in others, such as *simultaneous equations*, extensively taught in Asian high performers.

As for coverage specifically during the 8th grade, relative to number topics, according to teacher reports, algebra topics were more widely covered, indicating a shift of focus towards more advanced mathematics topics during the higher school grades, consistent with previous research findings by Baker and colleagues (2010) in the case of the United States. Differences in coverage between the two groups were statistically significant for all topics, except for *simultaneous equations*, showing more extensive coverage by teachers in high performers than in low performers. However, the average percentage across countries for each group shows a different picture. Low performers appear to have had broader coverage in two of the less challenging of the 5 algebra topics (e.g. for *simplifying and evaluating algebraic expressions* average coverage in LP = 65%; average coverage in HP = 55%), while the opposite was the case for the two more challenging topics, although differences are moderate (below 6%). These statistics depict the emphasis on algebra topics during the 8th grade in both low and high performers.

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47 The study considered content standards, textbook coverage, reported coverage by teachers, and allocated time.

48 The topic was reported taught by 100% of teachers in Chinese Taipei, 96% in Hong Kong, 100% in Japan, and 99% in Korea.

49 Pearson chi-square test results for the following topics: numeric, algebraic and geometric patterns – $x^2 (2) = 220.24, p < .001$; simplifying and evaluating algebraic expressions – $x^2 (2) = 84.53, p < .001$; simple linear equations and inequalities – $x^2 (2) = 32.35, p < .001$; representation of functions – $x^2 (2) = 78.27, p < .001$. 

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performers. They also show that differences in coverage of these topics between the two groups were not as pronounced as expected.

However, across countries, there is considerable variation as there is variation across the five algebra topics; such variation seems higher in low performers than high performers. In contrast to what previous studies of the mathematics curriculum have shown in relation to algebra topics, reported coverage in countries like Chile and Iran suggests that algebra topics were taught for the first time mostly during 8th grade. Teachers in high performing United States, on the other hand, also reported coverage of all but one algebra topic – numeric, algebraic and geometric patterns and sequences mostly – during 8th grade.

In all other countries or territories, there was variation in relation to the extent to which each algebra topic was taught during 8th grade. In Korea and Singapore most algebra topics were reported covered by about 60% or more teachers mostly during 8th grade. Chinese Taipei stands out as the high performing country where most teachers reported algebra topics as being taught mostly before 8th grade, depicting an enacted curriculum that advances more complex content topics earlier in the schooling progression.

Geometry topics

Geometry topics present a similar situation as algebra topics in relation to the variation in coverage. In the low performing country group, interestingly, Romania, which has shown more extensive coverage of all algebra topics and advancing some of these from earlier grades, as well as not covering number topics during the 8th grade but prior to, appears to be the one country where teachers reported more extensive coverage of almost all geometry topics by the 8th grade (5 of 6 topics are reported covered by more than 96% of teachers while the last topic has 77%
reported coverage). This broader coverage of most number, algebra and geometry topics in Romania, in comparison to all other countries, is surprising, given its lower performance levels. Explanations for such findings could be found in the strong influence of other factors on learning outcomes, such as classroom and school context, as well as students’ family background. Another possible explanation could be related to the depth with which these topics are covered, and the cognitive demands associated to them. Both of these as well as other explanations call for further research.

As for coverage of any single geometry topic across all low performing countries, only *geometry properties of angles and geometric shapes*, one of the more basic topics in geometry, appears to have been consistently taught during or before 8th grade (the minimum reported coverage is 90%). All other topics were covered in varying degrees. For example, one of the more complex topics – *translation, reflection and rotation* – showed wide variation in coverage by the 8th grade with a minimum of 7% in Ukraine and, interestingly, a maximum of about 90% in Thailand and Iran.

In contrast, in high performing countries, geometry topics were reported as covered either before or during 8th grade somewhat more consistently and to a higher extent (average coverage LP = 69.3; average coverage HP = 79.4). Broad coverage of 5 of the 6 (however, different) topics was reported for Japan and Korea (coverage over 92% across these 5 topics).

As for single topic coverage during or before the 8th grade across the high performing countries, as in low performing countries, *geometric properties of angles and geometric shapes* was the topic that appeared to be more broadly covered (by at least 87% of teachers across all countries or territories). Unexpectedly, variation in coverage across countries characterized all
other topics; for example, the topic translation, reflection and rotation was reported covered by 16% of teachers in Singapore and 97% in Japan.

Geometry topics coverage occurring mostly during the 8th grade shows similar variation as for algebra topics. However, overall geometry topics were covered less extensively during 8th grade than the latter in both low and high performers (average coverage LP = 39.7% and HP 34.7% for geometry topics; average coverage LP = 48.7% and 47.3% for algebra topics), which suggests that geometry topics were more likely to be covered in earlier years, suggesting a shift from higher to the earlier grades. Nevertheless, considering the country average percentage of reported coverage for each group, one of these topics – using appropriate measurement formulas for perimeters, circumferences, areas, surface areas, and volumes – was more broadly covered in low performers. This is consistent with findings by Schmidt and colleagues in 2001, which identified perimeter, area and volume as one of the two central topics of the 8th grade mathematics curriculum.

Furthermore, all six geometry content topics showed statistically significant differences in coverage between low and high performers.50 In most low performers, at least 2 of the 6 geometry topics were covered mostly during 8th grade, while this was the case in only three high performers (Hong Kong, Japan, and Singapore). Chinese Taipei once more stands out, but this time, in contrast to algebra topics, which were mostly taught before the 8th grade, for having devoted 8th grade almost entirely to the teaching of geometry topics, indicating a mathematics curricular progression that covers algebra topics prior to geometry topics.

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50 Pearson chi-square test results for the following topics: geometric properties of angles and shapes- x^2 (2) = 12.82, p < .05; congruent figures and similar triangles – x^2 (2) = 69.36, p< .001; relationship between three-dimensional shapes and their two-dimensional representations – x^2 (2) = 233.85, p < .001; using measurement formulas – x^2 (2) = 179.43, p < .001; points on a cartesian plane – x^2 (2) = 190.76, p < .001.
Data topics

Variation also characterized coverage of data topics before or during 8th grade across low and high performing countries and territories (ranging from 3 to 99%). In low performing countries, only Turkey’s teachers reported extensive coverage for all 3 of the data topics – above 97%. In high performing countries, only the United States showed broad coverage of all 3 data topics during or before 8th grade, with over 86% for any of the 3 topics.

Although the differences in coverage between low and high performers for each of the data topics mostly during the 8th grade were statistically significant, these differences were small, and coverage varied across countries. As expected, while teachers in low performers reported covering mostly the first two data topics during the 8th grade (*reading and displaying data* and *interpreting data sets, e.g. predict*), which are also the less advanced of the three topics, most teachers in high performers reported devoting their teaching during 8th grade to the more advanced of the three topics – *judging, predicting and determining chances*. Overall, for both low and high performers, reported coverage of data topics mostly during the 8th grade was lower than that reported for algebra and geometry topics.

Overall, most of the teachers (over 60%) in countries from both groups reported coverage of most topics in the 4 content areas (17 of the 19) during or before 8th grade. As for topics taught only during 8th grade, as expected, number topics were the least covered in the two groups, but to a lesser degree in high performing countries. In addition, consistent with the literature, algebra and geometry topics were the most emphasized topics of the 8th grade enacted.

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51 Pearson chi-square test results for the following topics: Reading and displaying data - $\chi^2 (2) = 271$, p < .001; interpreting data sets – $\chi^2 (2) = 25.18$, p< .001; judging, predicting, and determining chances – $\chi^2 (2) = 132.67$.

52 Although coverage of data topics was overall low in poor performing Chile and Lebanon while broader in Norway, it was reported to occur mostly during 8th grade in all three countries. Iran, Romania, Turkey, and Ukraine teachers reported at least 2 of the data topics as covered mostly prior to 8th grade. In high performing Japan, Korea, Singapore, Slovenia and the United States, at least one of the topics is reported as covered broadly mostly before 8th grade. In contrast, in Singapore 2 of the 3 data topics were reported as covered mostly in 8th grade.
curriculum in the majority of countries. In addition, the number of topics in each of these content areas and the specific topics chosen for this grade varied across countries or territories, showing varying opportunities to learn mathematics in these contexts.

4.1.3. Performance expectations in low and high performing countries

The second element of the mathematics OTL analyzed in this work relates to the cognitive processes that students go through as they learn and interact with the content, referred to in curricular documents as cognitive abilities, thinking skills or abilities, or performance expectations, among other terms. These processes were categorized in low demanding and high demanding performance expectations. The frequency with which each type of performance expectation was encouraged by teachers within and across groups during 8th grade is reported in the following paragraphs. Figure 4.3 shows the summaries of these frequencies for the two variables – LDPE and HDPE – across countries and the two groups (group composites).

Most teachers across countries reported covering both LDPE and HDPE at least in some lessons. As in the case of content topics taught, there was variation across countries within both groups, a finding that was expected and that is consistent with the findings of the 2001 study of the mathematics curriculum by Schmidt et al. Then, the analysis of textbook coverage for PE by content topics revealed variation across the TIMSS participating countries in terms of the space allocated to content demanding more complex performances.

Comparing group composites, as expected, coverage of LDPE was overall higher in low performers; 48.5% of teachers in low performing group reported covering LDPE in every or

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53 Activities reported in the teacher questionnaire were categorized and grouped into low demanding performance expectations (LDPE) and high demanding performance expectations (HDPE), according to the level of the thinking processes involved. Memorizing rules, procedures, and facts, for example, is considered low demanding while working on problems for which there is no obvious solution is considered high demanding.
almost every lesson, while in high performing countries, the percentage was nearly 10 points lower (39.8%). However, in the case of the HDPE findings did not meet the expectation that these would be covered more emphatically by teachers in high performers. A higher percentage of teachers in low performers reported covering HDPE with the highest frequency – for every, or almost every, lesson –, that is 29.9%, than did teachers in the high performing group - 11.7%. Moreover, while 72% of teachers in low performing countries reported covering HDPE during either half of the lessons or for every, or almost every, lesson, only 46% of teachers in high performing countries reported doing the same.

To test the differences in the use of LDPE and HDPE by teachers between low and high performers, Pearson’s chi-square test was used. In the case of LDPE, differences were statistically significant, \( X^2 (3) = 41.35, p < .001 \); however, Cramer’s statistic (.096, \( p < .001 \)) indicated a very weak effect of low demanding performance expectations on mean mathematics performance. In the case of HDPE, Pearson’s chi-square statistic indicated that teachers’ use of HDPE was significantly different between the low and high performing groups, \( X^2 (3) = 373.52, p < .001 \). The percentages, as well as the statistically significant standardized residuals (\( z= .43 \) and \( z= .47.2 \) for low and high performing countries, respectively) and Cramer’s statistic – .29 – confirm these differences: overall teachers in low performing countries used HDPE frequently - in every or almost every lesson – to a significantly higher extent than teachers in high performers.

According to earlier studies of the mathematics curriculum and student learning (see for example Gamoran et al. 1997; Porter 1998; Valverde 2004, 2010), teaching more challenging thinking skills results in higher student achievement. Hence, regardless of whether teachers in high performers cover HDPE sufficiently to elicit high student achievement, the lower emphasis
on HDPE made by teachers in high performers in comparison to low performers, inconsistent with the literature, demands further analysis.

Some hypotheses are suggested for future studies. First, and perhaps the more likely, the pronounced and unexpected differences between low and high performers may be due to measurement error. In developing countries – in many cases also the low performers –, where policy change may occur at a slower pace given the higher prevalence of obstacles for enacting curricular policy (discussed in the literature section), there is more room for misinterpretation of the concepts and representations of more cognitively challenging teaching processes. Teachers in these countries could, therefore, give other meanings to the actions referred in the survey as those that promote higher order thinking processes.

Another possibility is that teachers have adopted the language of more demanding performance expectations, following policy change and a discourse that strongly promotes them, but translate these goals into actions inaccurately, not having had the necessary training. They, then, report a believed emphasis on these processes. Teachers in high performers, on the other hand, who may have had access to the opportunities to learn to teach for HDPE and are aware of the demands on teaching as well as learning of these types of PE, report a reality that more accurately corresponds to these more challenging thinking processes. Teachers could also be providing answers that they believe are the “right” answers, a matter of desirability.

Figure 4.3 depicts the emphasis made by teachers with each type of PE across countries in both groups. High performing countries and territories show much less variation in the coverage of HDPE; the majority of teachers in these countries reported covering HDPE only in some lessons and very little in every or almost every lesson, while only Norway and Ukraine,
two of the three European countries in the low performing group, show this same pattern. Low performing Chile is the country, across all, with the highest percent of teachers that reported covering HDPE in every or almost every lesson on average – 55% –, which contrasts with the corresponding highest percentage in the high performing group – 21.8%.

As for the LDPE, in some low performers the majority of teachers (above 60%) reported covering LDPE with the highest frequency – in every or almost every lesson -, specifically Indonesia, Lebanon, and Ukraine. In contrast to the lower emphasis on HDPE, most teachers in the high performing group made a strong emphasis on LDPE, especially in Chinese Taipei, Japan, Korea, Russian Federation, and the United States. Such emphasis may be indicative of the importance of mastering these more basic skills before moving towards more challenging thinking processes. Knowingly, teachers in high performers perhaps ensure the acquisition of these more basic thinking abilities by continuously covering them. On the other hand, more in line with scholarship related to high stakes standardized testing (Lesh and Zawojewski 2007), teachers possibly respond to the stronger emphasis made in these assessments of the more basic thinking skills.

Although teachers’ coverage of LDPE and HDPE did not seem to be correlated in either group, the association of teachers’ focus on LDPE with that on HDPE during the 8th grade was tested. The assumption made was that, given time constraints, teachers’ strong emphasis on one of the PE may leave little time for activities related to the other type of PE. Pearson chi-square test and the Spearman’s correlation test were used, specifically for these non-normally distributed data. The standardized residuals for each frequency count were observed along with correlation coefficients.

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54 In eight out of 9 high performing countries more than 50% of teachers reported covering the HDPE with a lower frequency (in some lessons only).
Test results for the relationship between emphasis on LDPE and HDPE in low performing countries indicate a small association between the two. Standardized residuals indicate significant differences in the proportions of teachers making more and those making less emphasis on HDPE (for every or almost every lesson \( z=5.2 \); for only some lessons \( z=-5.5 \)). For example, a higher percentage of teachers who covered LDPE in every or almost every lesson tended to cover HDPE also in every or almost every lesson than would be expected given no association. Nevertheless, according to Gamma statistic, .378, the association between the use of LDPE and HDPE was moderate in low performing countries.\(^{55}\) Supporting these results, the Spearman’s rho correlation statistic for LDPE and HDPE was .28, statistically significant (\( p<.001 \)), indicating a weak relationship between these two variables.

The association found between the emphasis made on LDPE and that placed on HDPE is considerably less important in the high performing group of countries or territories. Standardized residuals were significant and showed patterns in the proportions of teachers making less or more emphasis on HDPE. Gamma statistic, however, -.221-, indicates a weak association between teachers’ use of the 2 types of PE. This is supported by the small Spearman’s rho correlation coefficient -.16 (\( p<.001 \)).

The weak associations in the emphasis made on LDPE and HDPE found in both low and high performers is not sufficient to make definitive conclusions about teachers’ decisions in relation to activities that promote certain types of PE. However, higher independence of teachers in high performers along with a high emphasis on LDPE and reduced focus on HDPE may indicate more deliberate or analytical decision-making processes by teachers in high performers. Teachers in low performers, on the other hand, possibly focus on delivering expected mathematics content, within less reflexive teaching processes. Findings in relation to the

\(^{55}\) Gamma statistic is used specifically for ordinal variables.
emphasis made in each of the two PE and academic performance do call for further analysis that look both into teachers’ instruction, as well as tendencies in teachers’ responses.

4.1.4. Instructional strategies in low and high performing countries

The third element of the mathematics curriculum defining OTL included in this analysis is instructional strategies (IS). As in the case of PE, these instructional activities reported were categorized into low and highly cognitively challenging (LCIS and HCIS).

Figure 4.4 depicts the frequency with which teachers employed LCIS and HCIS during 8th grade across countries and territories in each group. The percentages of teachers that reported emphasis on each type of IS showed similar variation across countries within groups and more similarities than differences between them. The group composite percentages show that teachers’ use of LCIS was similar across the two groups; 34.3 and 33.8% of teachers in low and high performers, respectively, employed these LCIS in every or almost every lesson, while 56.6 of the low performers and 54.6% of high performers used these strategies in half the lessons. In both groups the vast majority of teachers used LCIS at least in half of the 8th grade mathematics lessons.

As for HCIS, a small difference between the groups is noted: 54% of teachers in LP used these strategies for about half of the 8th grade lessons, while 60% of teachers in HP reported doing the same. A higher difference was found between low and high performers in the extent to which teachers reported using HCIS with the highest frequency, in every or almost every lesson;

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56 These are drawn from teachers’ responses about different teaching techniques they employed in the teaching of mathematics to their 8th grade students.

57 The frequencies for these two variables are an average drawn from different activities.
the percentage for LP is 12 points above that of HP (30.4% and 18%), a finding that is similar to that for HDPE.

To determine whether differences seen in teachers’ use of IS are statistically significant, Pearson’s chi-square test was used along with Cramer’s V statistic. In the case of LCIS, although Pearson’s chi-square statistic is significant, $X^2 (2) = 8.22, p < .05$, the standardized residuals are not statistically significant, indicating no significant differences in the use of LCIS between the two groups.

As for HCIS, Pearson’s chi-square statistics show a significant association between teachers’ emphasis on these strategies and mean country performance $X^2 (3) = 140.14, p < .001$. For coverage in every or almost every lesson the standardized residuals suggest a statistically significant difference between low performing countries ($z=6.3$) and high performing countries or territories ($z=-5.7$). As in the case of PE, the frequent use of HCIS appears to have been more accentuated in low performing countries. Once again, these findings, which are inconsistent with expectations and the reviewed literature, posit important questions for future research.

Overall, as in the case of PE, the results of the analysis do not support the hypothesis of a positive association between using more challenging IS and higher mean performance. Although the opposite is not said to be the case, the findings elicit similar questions and hypotheses as those discussed in the case of PE.

4.1.5. Instructional time in low and high performing groups and across countries

The final element of OTL considered in this study is instructional time (IT). The skewness and kurtosis statistics for the low or high performing groups indicate the data for
yearly IT are not normally distributed. Separate country statistics also revealed that the IT per year variable is not normally distributed in any of the countries. Given the non-normal nature of the distributions, a non-parametric test was chosen to test the differences in the mean and distribution of mathematics instructional hours per year between the two groups and among countries and territories.

Figure 4.5 shows the distribution of yearly mathematics instructional hours across the two groups of countries – low and high performers. After eliminating outliers (< 5) in both groups of countries, some differences stand out between the two distributions. The total variance for low performers is larger than that of high performing countries by more than 1000 hours (2647.77 and 1565.25). Moreover, considering individual countries or territories, since variances for the whole group may not necessarily mean variation within countries, the variance of most high performing countries or territories is smaller than that of low performers; the average variance for the first is 1168.52 while for the latter it is 2216.98. These differences can be observed in the Boxplot in figure 4.5 and indicate that there is considerably less variation in the amount of IT that teachers in high performers reported employing for mathematics teaching than there is in low performers. Less variation may be indicative of better correspondence of teachers’ instruction with intended IT, a hypothesis that will be discussed further when intended time for mathematics instruction is compared to actual instructional time.

Finally, IT statistics suggest that teachers in low performing countries in general reported taking more hours to teach mathematics during the 8th grade, although the difference is small: the median for low performers, 140, is higher than high performers by about 13 hours. To test the difference between reported mathematics instructional hours per year of low and high performing countries, the Mann-Whitney test was used, appropriate for non-normal distributions.
According to the test, the number of mathematics instructional hours per year in low performing countries (Mdn = 140.25) is significantly higher than in high performing countries (Mdn = 126.81), U = 1804486, z = -6.508, and, r = -.10, which represents a very weak (negative) association between instructional time and mean achievement.

Figure 4.6 further describes the distribution of reported hours of mathematics teaching and the error bar chart for this variable for all 19 countries. Countries with the lowest amount of yearly mathematics IT were Finland, Japan, Turkey, Slovenia, and Norway, countries from both high and low performing groups. Countries with the highest amount of yearly instructional hours were Chinese Taipei, Indonesia, Lebanon, and Chile, mostly low performing countries.

Finland and Japan, countries that had no significant difference in mean instructional time, according to the post hoc test, had different distributions. IT reported by Japanese teachers revealed much less variation than reports of IT in Finland (Var Japan = 513.39; Var Finland = 767.84).

As expected, findings in relation to mathematics IT show clear differences between low and high performing countries or territories. Low performers show more within country variation of mathematics IT. It could be hypothesized that in high performers, policies have play a better role in supporting teachers in the enactment of the curriculum. Finally, given the similarities, findings also indicate commonalities in the structure of schooling across countries, mostly within groups, but also across groups, in terms of the time given to the subject.

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58 Differences in yearly mathematics IT were also considered across countries within and across groups. To test differences among countries, the Kruskal-Wallis test was used, appropriate for non-normal distributions. The test statistic shows that mathematics instructional time per year was significantly different across countries, H(18) = 1213.97, p < .001. In order to identify where differences lie, post hoc tests for the Kruskal-Wallis test were used, testing each country against all others. Critical differences were calculated for each pair of countries and compared to the differences between the pair in the mean ranks given by the Kruskal-Wallis test. Differences were not significant for several pairs of countries, including Chinese Taipei and several low performing countries, Indonesia and half of low performers, Thailand and half of high performers, and Japan and one low performer and one high performer. There were similarities in the distributions found in countries across the two groups, and more across low performers and among low and high performers than across only high performers.
Instructional time per content area

The percentage of time devoted by teachers by content area during the 8th grade was also examined. Table 4.1 shows descriptive statistics for number, algebra, geometry and data topics for each group. Mean percentages of instructional hours show that teachers in high performing countries or territories on average devoted considerably more time to the teaching of algebra in the 8th grade than is the case of teachers in low performing countries, while teachers in low performers appeared to devote slightly more time to number and geometry topics. The Mann-Whitney test was used to test differences. The differences in the percentage of instructional hours devoted to number, algebra, and geometry topics between the two groups were found significant (p<.001), UN= 2073395, UA = 1922404, and UG= 1910643, zn = -8.749, za = -8.153, and zg = -8.749. Only the difference in the percentage of time devoted to data topics between low and high performers was not found statistically significant.

Figures 4.7, 4.8, 4.9, and 4.10 depict the distribution of the percentage of time devoted to each content area by country. The boxplots show that most low performers, except for Ukraine, devoted more time to number topics during the eighth grade. Figure 4.9, on the other hand, shows that most high performers, except for Slovenia and to some extent Korea and Japan, devoted a higher percentage of their mathematics instructional time to algebra topics, which coincides with teachers’ reports of content topic coverage, and with previous research findings (Baker et al. 2010; Schmidt et al. 2001).

The variation in coverage of number topics is higher in low performers, particularly in Iran, Indonesia and Chile. However, for algebra topics the variation is more pronounced in high performers, specifically Russian Federation, and Chinese Taipei and Finland. Notably, the
United States shows a much wider distribution, a result likely due to the decentralization of curricular decisions to the state and district level and the relatively recent push for the introduction of algebra topics earlier in the school progression given the poor results of in TIMSS in the 1990’s, along with call for reform in this direction by the National Council of Teachers of Mathematics (NCTM).

In the case of geometry topics, figure 4.10 shows that countries vary in the percentage of time devoted to these, and the same occurs for data topics, which are given less time across all countries. Chinese Taipei, Lebanese and Russian teachers stand out for reporting having devoted most time during 8th grade mathematics to algebra and geometry topics in larger numbers. Interestingly, the vast majority of teachers from Chinese Taipei reported not having covered algebra topics during the 8th grade, which, once again, casts doubt on the validity of teacher reports.

Overall, differences are found in central measures of IT among most countries or territories within and across groups. Teachers in low performing countries in general employed more hours to the teaching of mathematics than teachers in high performers, the difference being statistically significant. However, most of the difference lies in the variation of reported IT within countries and, notably, across countries in the two groups. In low performing countries, in general, there is more variation in the reported IT than that seen in high performers. These findings suggest that, as expected, more teachers were in correspondence with intentions for IT in high performing countries or territories than in low performers.
4.2. Mathematics curriculum intentions and the enacted curriculum

This section presents the results of the analysis of mathematics curricular intentions of each of the 19 countries considered in the study in relation to the enacted curriculum reported by teachers. As discussed in the previous chapters, curricular intentions reflect national curricular policy, the knowledge and skills students are expected to learn; the data for curricular intentions were drawn from the national curricular questionnaire responses given by national experts. Three of the four elements of OTL are analyzed here: mathematics content topics, PE and IT. Instructional strategies are omitted since the national curriculum questionnaire does not cover them. The inclusion or lack thereof in the curricular intentions of each of the 19 topics was examined in relation to the extent to which it was covered by teachers in each country. PE were compared with the degree of emphasis in intentions and actual coverage. Finally, the measure used for IT is the percentage of IT devoted to teaching mathematics in eighth grade of all instructional time during the year.

4.2.1. Content topics in low and high performing countries

Table 4.3 shows the inclusion of each of the 19 content topics in countries’ curricular intentions. The number of countries in each group that intended topics to be taught before or during 8th grade, taught only during 8th grade, taught only before 8th grade, or that didn’t intend topics to be

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59 In the case of content, all 19 topics reported by teachers were also reported by curriculum experts regarding whether they were intended to be taught to most students and the grade or grades for which they were intended.

60 The items in the national curriculum questionnaire that inform of intended coverage of certain PE do not correspond exactly to the PE reported by teachers. Nevertheless, these are classified into low demanding and high demanding, as are the PE reported by teachers, for the purpose of comparing intentions and enactment.
taught up to 8th grade is listed. The table also includes the number of countries that included topics in their curricular intentions throughout three or more grade levels.

According to the national experts’ responses, all countries in both groups included all number topics in their curricular intentions before or during 8th grade. The majority of low and high performers included these topics in grades prior to 8th, but not all continued to prescribe them for grade eight. The topic concepts and computing with fractions, for example, considered one of the most important topics and more difficult to grasp by students, was also intended to be taught in grade 8, in addition to prior grades, by less than one third of countries in each group. Furthermore, the more advanced topic, problem solving using percents and proportions, was still prescribed for grade eight in about fifty percent of low performers and a third of high performers.

Algebra topics were to be introduced before the 8th grade in some countries in both groups, consistent with the findings from previous studies (see Schmidt et al. 2001; Schmidt et al. 2002). Some differences were noted, however, between low and high performers. Most low performers intended for the first three algebra topics to be taught before or during 8th grade or both, but in the case of two algebra topics, simultaneous (two variable) equations and representation of functions, about half of low performers did not intend them to be taught by this grade level. This finding suggests that more low performers had the intention of introducing the more advanced algebra topics until after 8th grade, if they were included in the curriculum. In high performers, in contrast, nearly all countries intended for all five algebra topics to be taught by the 8th grade, and the majority also intended them to be covered during 8th grade.

In comparison, the 2002 study by Schmidt and colleagues identifies that two thirds of the top achieving countries intended the topic equations and formulas to be introduced in the 3rd grade, while all countries intended such topic to be taught in the 7th grade. The other algebra
topic examined – *patterns, relations, and functions* – was intended to be taught for the first time during the 8th grade only by two thirds of the top achieving countries, while in 2011, 5 low performers and 2 high performers intended to introduce this topic prior to 8th grade. The findings of this study, then, suggest that algebra topics have continued to move towards earlier grades after this 2002 study.

Geometry topics were also intended to be introduced before 8th grade in both low and high performers. As in the case of algebra topics, more high performers included all geometry topics in their curricular intentions before or during 8th grade than is the case of low performers. In the case of *relationship between 3-dimensional shapes and their 2-dimensional representations*, for example, only half of low performers included the topic in their curricular intentions for 8th grade or prior, while nearly all high performers did so. Moreover, the topic *translation, reflection and rotation*, one of the more advanced geometry topics, although intended by 8th grade by the majority of countries in both groups, was to be introduced before 8th grade by six high performers while only three low performers. In more than half of high performing countries the first two geometry topics – *geometric properties of angles and geometric shapes* and *congruent figures and similar triangles* – were intended to be taught before and in 8th grade, while this was the case for less than a quarter of low performing countries.

In comparison, in the 2002 study Schmidt et al. revealed that *two-dimensional basic geometry* topics were intended to be taught by two thirds of the top achievers beginning in 3rd grade, while *polygons and circles* as well as *perimeter, area and volume* were to be introduced in 4th grade by more than 80% of the countries. Other geometry topics were also considered for higher grades of primary education, such as *two-dimensional coordinate geometry*, prescribed
for the first time for grade 5 in two thirds of the top achieving countries, and *transformations*, to be introduced in grade 6 in more than 80% of the countries. The comparison suggests that, although geometry topics were present in the curriculum from earlier grades to a higher extent than algebra topics, more complex geometry topics have also moved towards earlier grades, particularly in high performers.

The inclusion of data topics in curricular intentions by the 8th grade also occurred in both low and high performers, as expected. *Reading and displaying data* is a topic that was intended to be covered mostly before 8th grade (and not for 8th grade) in about half of the countries in both groups. In addition, unexpectedly, more than half of the high performers excluded the more complex data topic – *judging, predicting, & determining* chances – from intentions by the 8th grade, while the majority of low performers did include it by this level. In contrast, data topics, according to the 2002 study mentioned above by Schmidt et al. were to be introduced in the 3rd grade in two thirds of the top achieving countries, with the topic *data representation and analysis*; however the inclusion of other data topics in the intended curriculum was not explored by such study, which also suggests that, although data topics have been gathered much less attention in the mathematics curriculum than algebra or geometry topics, their presence has also increased in the curriculum prior to grade 8.

The analysis of curricular intentions to uncover the inclusion of topics consistently throughout the schooling progression revealed that in both groups there are countries that intended for most topics to be taught in more than one grade level. Most countries in both groups intended for most topics to be covered in more than three grade levels, from preschool through grade 12. Specifically, in the low performing group, Norway intended for teachers to continue covering topics in at least three and at the most eight grade levels. Similarly, Iran, Morocco,
Romania, and Thailand’s curricular policies established topics to be covered consistently, with Iran prescribing an algebra topic in eleven grade levels.

The United States stands out as the country, from all 19, that intended continuous coverage of mathematics topics. On average, the 19 topics were to be covered in seven grade levels (at least four and 12 at the most). But other high performers also prescribed the teaching of topics throughout several grade levels. Hong Kong, Russian Federation, Singapore, Slovenia, and Finland stand out for having intended most topics to be taught in more than three grade levels. On the other end, low performing Chile, Indonesia, and Lebanon and high performing Chinese Taipei intended for most topics to be taught in only one grade level. In comparison, the TIMSS 1995 curricular reports examined by Schmidt et al. (2002) showed that the majority (more than two thirds) of countries intended 17 of the 33 topics in the framework, a mixture of less and more complex content topics, to be covered in more than three grade levels.

Some topics appeared more consistently in curricular intentions across countries. In low performing countries computing, estimating or approximating, concepts and computing with fractions, numeric, algebraic and geometric patterns, geometric properties of angles and geometric shapes, and using measurement formulas were the topics most consistently intended, which are some of the more basic topics in number, algebra and geometry content areas. In high performers, these same topics were also intended throughout several grades more than all others. In addition, many high performers also prescribed simplifying and evaluating algebraic expressions, representations of functions, congruent figure and similar triangles, reading and displaying data, and interpreting data sets, algebra, geometry and data topics that are considered more advanced. The number of countries is small to make definitive conclusions, and variation is present in both groups in terms of the inclusion of topics and the intention to cover them.
throughout several grade levels. However, some differences stand out. More high-performing countries or territories seemed to introduce algebra and geometry topics before the 8th grade. They also appeared to cover more of these topics throughout several grades. The United States, in particular, consistent with studies by Schmidt and colleagues more than 10 years ago (2001), seems to continue to include a wide range of topics in each grade, with most of the topics being intended to be taught in five or more grade levels. Although more specific conclusions cannot be made regarding the inclusion of topics in curricular intentions in several grades and its relation to achievement, findings in relation to the extent to which these intentions were indeed carried out by teachers suggest that the relationship between curriculum and achievement is complex. More is discussed in the following analysis of the relationship between intentions and enactment.

4.2.2. Content topics intended and enacted across countries during 8th grade

Figure 4.11 shows the inclusion of each content topic in curricular intentions specifically for the 8th grade or equivalent, and teachers reported coverage during this same year for low and high performing countries. This chart reflects the topics that countries intended to be taught during 8th grade. It also reflects which content areas were more commonly considered in countries intentions at this point, and the extent to which teachers in each country were in correspondence with these intentions, both in percentage of teachers and by the number of topics that teachers in general actually covered.

Number topics, introduced mostly in earlier grades, were the least included in curricular intentions in 8th grade. However, low performers (Iran and Morocco) as well as high performers (Slovenia and the United States) prescribed all 5 of the number topics for this grade level. While most high performers did not intend number topics for grade 8, five countries in the low
performing group included from one to four of the number topics in their 8th grade intended curriculum (Chile, Norway, Romania, Turkey, and Ukraine).

Although these differences between low and high performers in regarding curricular intentions were not surprising, the analysis of the enacted curriculum in relation to intentions during grade 8 did show unexpected findings. Particularly in number topics, which are assumed to have been extensively covered by the 8th grade, teachers’ reported enactment of the curriculum reveals wide gaps between teaching and intentions throughout countries in both low and high performers. Less than 50% of teachers covered number topics in the four countries where all of these topics were intended – two low and two high performers. In Chile and Norway, which prescribed two of the number topics for 8th grade, only about two thirds of teachers covered these intended topics. In low performing Turkey, where four of five number topics were prescribed, less than 7% of teachers reported covering any of the topics, and in high performing Finland, only one of the two number topics prescribed (problem solving with percents and proportions) was reported taught by the majority of teachers (65.8%), while the other is covered by less than 5%.

On the other hand, in Norway and Thailand, a considerable percentage of teachers reported covering number topics, which were not included in curricular intentions for grade 8 – more than 50% of teachers in Norway and from about a fourth to three fourths of teachers in Thailand. Similarly, in high performing Korea, number topics were reported covered by up to 2 fifths of teachers although none of these were intended.

These results are inconsistent with the argument that teachers’ strict correspondence with curricular intentions is a necessary condition for high student achievement. The reported coverage in each group indicates teachers make conscious decisions about whether to cover not

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61 Iran and Lebanon in low performers and Slovenia and the United States in high performers.
intended topics or not to cover intended topics. In high and low performers, teachers possibly make decisions about covering number topics intended for previous grades when students have not mastered the knowledge needed to move into more complex topics. Such case, as well as the decision not to cover intended topics, reflects teachers responding to contextual elements, exercising certain autonomy and, in that, defining curricular policy.

As shown in Figure 4.11, algebra topics were more widely considered in curricular intentions and actually covered by teachers in 8th grade. This is consistent with the literature (see Baker et al. 2010; Schmidt et al. 2001), which indicates that algebra topics, although more recently introduced in earlier grades in some countries, are especially emphasized in secondary school (ranging from grades 6-9). However, there is still considerable variation across countries in the extent to which these topics are covered and some differences between the two groups. Low performers Iran, Romania, Turkey and Ukraine intended most (4 or 5) of the 5 algebra topics to be taught during 8th grade, as was the case of high performing Finland, Hong Kong, Korea, Singapore, and the United States. Low performing Chile, Indonesia, and Lebanon, however, considered two or less algebra topics for their 8th grade curriculum, as did only high performer Chinese Taipei.

As with number topics, there is a wide gap between these intentions and actual teacher coverage in all countries. A considerable percentage (above 50% for some topics) of teachers in Chile, Indonesia, Lebanon, and Norway reported coverage of algebra topics that were not prescribed for the 8th grade, which was not the case in high performing countries. In contrast, coverage of prescribed algebra topics was reported by less than 50% of teachers in at least one of the 5 topics in all low performers, except for Turkey and Indonesia, the latter of which didn’t prescribe algebra topics for most of its students. In Iran, as shown in figure 4.11, only 30% of
teachers reported covering the topic *representation of functions*, when according to the intended curriculum it was to be learned by all students in the 8th grade. Norway and Ukraine stand out as countries where intended coverage was minimal.

This low coverage of intended algebra topics also occurred for some topics in high performing Chinese Taipei, Finland, Hong Kong, Japan, Singapore, Slovenia and the United States. Although the average coverage of algebra topics in the two groups is similar, the average percentage of teachers that reported coverage of not intended algebra topics in the low performing group is two times that of high performers (37.7 and 18.5%), suggesting low performers diverged more from curricular intentions. Geometry topics were also an important part of the 8th grade curriculum in many countries. Half of the low performing countries as well as two thirds high performers prescribed at least 4 of the 6 geometry topics. Only Chile, Indonesia, and Lebanon and Asian high performers Chinese Taipei, Japan, and Korea prescribed two or less of these topics.

The gap between intentions and enactment seen with number and algebra topics was also present with geometry topics in all countries. In no low performing countries were all intended geometry topics covered by more than 50% of teachers, while this was the case for 5 of the high performers. Iran, Morocco, and Norway stand out as cases where 4 or more topics are intended but are reported as minimally taught (as few as 13% of teachers). Finland, Hong Kong, Slovenia, and the United States also stand out for this reason. In the United States and Finland, where all geometry topics were intended, these have a reported coverage lower than 50%. In contrast to algebra topics, it is high performers that reported a lower average coverage of the intended geometry topics in comparison to the low performers (38% to 48%), while coverage of not intended topics in the two groups was similar (28 and 34% for high and low performers).
Data topics were included in the intended curriculum for 8th grade to a lower extent in comparison to algebra and geometry topics, especially in the low performing group. Half of the countries in this group did not prescribe any of the data topics in the framework and only Iran and Romania considered all 3 to be taught in 8th grade. In the high performers, only Chinese Taipei did not intend any of the 3 data topics to be taught, while the United States is the only one to have intended all 3 data topics.

Once again, intentions did not correspond to the actual coverage of data topics in most cases. Average coverage of intended topics in the low performing group is 32.9%, similar to that of the high performing group – 34.8%. In Iran and Romania only about 32% of teachers reported covering any of the data topics, all intended for 8th grade. In high performing Finland, less than 3% of teachers reported covering the 2 intended data topics; teachers in Korea, Singapore, Slovenia and the United States also reported low coverage of intended data topics. On the other hand, coverage of not intended data topics was considerable in some low performers, where up to 47% of teachers reported covering them. In high performers, however, coverage of not intended topics was low (13.3% on average), which could indicate a lower need for teachers to cover topics because of lack of mastery.

Figures 4.12 to 4.16 depict intentions and enactment of all content topics for before or during 8th grade by country. The inclusion of each of the 19 content topics in each country’s mathematics curriculum is shown in contrast to the percentage of teachers that reported coverage. While the previous analysis considers intentions and enactment only for 8th grade, the charts in figures 4.12 – 4.16 consider these prior to or during 8th grade.

The analysis reveals that low performing Iran, Romania, and Thailand and high performing Finland, Japan, Korea, Russian Federation and the United States all had 18-19 of the
19 topics from the framework in their intended mathematics curriculum for the majority of students up to 8\textsuperscript{th} grade. Low performing Indonesia, Morocco, Norway, and Ukraine, on the other hand, excluded from 5 to 7 of the 19 topics from their curricular intentions up to 8\textsuperscript{th} grade, while in high performers 4 topics are excluded at the most in Chinese Taipei and Slovenia.

In few cases topics were only intended for the more able students. Such is the case of low performing Lebanon, with 2 geometry topics, and Indonesia with 3 algebra topics and 1 geometry topic, as well as high performing Hong Kong, with 2 geometry and 2 data topics. When considering only those topics that were intended for the majority of students, low performing Indonesia stands out as only intending 8 of the 19 topics from the framework in their preschool through 8\textsuperscript{th} grade curriculum. Hong Kong also stands out as the high performer with the lowest number of topics from the framework intended for the majority of students – 15.

When looking at intentions versus enactment up to 8\textsuperscript{th} grade, in contrast to observing only 8\textsuperscript{th} grade data, the gap between these appears narrower, although it is still pronounced in some countries and for some topics. Only in the case of Hong Kong, the United States and Turkey did more than 2/3 of teachers report coverage of all intended topics during or prior to 8\textsuperscript{th} grade. In low performing Romania and high performing Japan, Korea, and Singapore more than 50\% of teachers reported having covered the intended topics. Indonesia poses a particular case:\textsuperscript{62} of the 8 intended topics, 7 were reported as taught by more than 90\% of teachers, but the 4 topics intended for only the more able students were also reported as taught to this extent. Ukraine and Thailand also show relatively high levels of correspondence, with 13 out of 14 and 16 out of 18 intended topics, respectively, reported taught by more than 2/3 teachers. Notably, more high

\textsuperscript{62} Indonesia’s intended curricular data may be problematic. The responses in the national curriculum questionnaire reported that number topics were not intended to be covered all through 8\textsuperscript{th} grade. However, in reports about whether a topic is intended to be covered in specific grades (from preschool to 12\textsuperscript{th} grade), it was indicated that number topics were intended to be taught during 7\textsuperscript{th} grade; that is, the questionnaire responses show contradicting information.
performers show higher levels of correspondence between the intended and the enacted curriculum.

Lower levels of correspondence were identified in more of the low performers. While 8 of the low performing countries (Chile, Indonesia, Iran, Lebanon, Morocco, Norway, Thailand and Ukraine) have from 1 to 5 intended topics for which less than 50% of teachers reported as covered, only 2 high performers (Finland and Slovenia) do so. Moreover, in 5 of these low performers less than one quarter of the teachers reported 1 or 2 of the intended topics as covered.

As for topics that were not included in the intended curriculum, in some countries some of these topics were reported as taught during or before 8th grade by more than 50% of teachers. Such was the case in 7 low performers and 5 high performers. However, in most of these cases, it was only one topic that followed this pattern. Only in low performing Chile and Indonesia were 2 and 5 not-intended topics, respectively, reported as taught by more than 50% of teachers.

The comparison of the enacted with the intended mathematics curriculum from grades 1 to 8 across low and high performers reveals the gaps between these two levels of the curriculum that remain even when considering intentions that expand through several grades in both low and high performing education systems. Some of the factors discussed in previous chapters can be considered in explaining the lack of correspondence, including poor teacher preparation, textbook content that diverges from intentions, lack of teacher support, or students’ poor mastery of topics from previous grades. Besides these and other reasons posited in previous studies, which seem to be more prominent in developing, often low performing countries, whether teachers have sufficient time to cover intended topics in depth rather than superficially during each school year, given the complexity of topics as well as performance expectations, should also be considered in examining teachers enacting of the curriculum.
Overall, contrary to what was expected, the analysis of the relationship between intended curricular content and teachers’ enactment reveals that a large gap exists between these two curricular dimensions in both low and high performing countries and territories (see figure 4.17 for some country cases from both low and high performers). Although the differences are more prominent in some low performers, the considerable degree of divergence in all four content areas found in high performers is contrary to the idea of a world-class mathematics curriculum, which is assumed will be delivered by teachers, as a sufficient condition for high mathematics achievement. The question in this case is not whether being exposed to a more challenging curriculum translates into higher achievement, as researchers argue (Gamoran et al. 1997; Porter 1998; Valverde 2004), but, rather, whether establishing more challenging curricular standards guarantees that students will be exposed to such.

4.2.3. Intended and enacted performance expectations during 8th grade

Figure 4.18 shows, for each country or territory, the inclusion and emphasis intended of three PE in the mathematics curriculum for grade 8: mastering basic skills and procedures, applying mathematics in real life contexts, and reasoning mathematically. Each chart also shows the extent to which teachers reported covering these PE in grade 8 of formal schooling. As discussed in the literature and stated in Chapter 3, PE can be catalogued as low demanding and high demanding according to the complexity of the thinking processes involved. Of the three PE, the first were identified as low demanding and the latter two as high demanding. The analysis of the intended and enacted PE begins with the comparison of PE intended across countries or benchmarking territories and between groups.
The intended PE for at grade 8 varied across countries and territories. Nevertheless, some differences stand out between low and high performers; I note that given the low number of countries in each group these are not statistically significant or conclusive. While 8 of 9 high performers prescribed a lot of emphasis on the more basic of the PE, *mastering basic skills and procedures*, only 6 of 10 low performers did so. As for the more demanding PE, one third of low performers intended a lot of emphasis on *reasoning mathematically*, while about half of high performers did so. Noticeably, all high performing Asia-pacific countries and territories, except for Chinese Taipei, intended a lot of emphasis on this PE.

Furthermore, low performing Thailand and Turkey and high performing Finland, Japan, Korea and Singapore intended a lot of emphasis on all three PE. In nearly all low performers (except for Norway) and all high performers, a lot of emphasis on the two more demanding PE was intended along with a lot of emphasis on the more basic PE – *mastering basic skills and procedures*; thus, when this latter PE was only given some emphasis in intentions, the other two were intended with the same or less emphasis. This emphasis on both kinds of PE is consistent with the scholarship that posits that mastering the more basic PE is as necessary and important as the more complex thinking processes.

Figure 4.18 depicts the correspondence between intentions and enactment in terms of PE for each country.63 The statistics show that there were similarities among some of the countries within each group as well as differences between them. The strong emphasis intended in high performers for the more basic PE, *mastering basic skills and procedures*, was only reported by

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63 As explained in chapter 3, in order to compare intentions with enactment for PE, items from the teacher questionnaire were matched to the three PE reported for intended curricula as follows: 1) *Mastering basic skills and procedures* with teachers reported activity for *apply facts, concepts, and procedures to solve routine problems*, 2) *Applying mathematics in real life contexts* with teachers reported activity for *relate what they are learning in mathematics to their daily lives*, and 3) *Reasoning mathematically* with teachers reported activity for a) *explain their answers*, b) *decide their own procedures for solving complex problems*, and c) *work on problems for which there is no obvious solution*. 123
most teachers in Korea, Russian Federation, and the U.S, in which close to two thirds more of teachers reported covering these in every or almost every lesson. Teachers’ strong emphasis on these PE, when intended, was only seen in low performing Ukraine, in which over 80% of teachers reported covering *mastering basic skills and procedures* in every or almost every lesson, while less than 50% of teachers in the other 5 low performing countries that intended a lot of emphasis on these LDPE promoted these with high frequency.

Moreover, the use of the more demanding PE – *applying mathematics in real life contexts* and *reasoning mathematically* – did not correspond with intentions notably in more high performers than low performers. In Iran and Norway, for instance, the strong intended emphasis on *applying mathematics to real life contexts* was reported by 29% and 11% of teachers, respectively, who said they had covered these PE in every or almost every lesson. In high performing Finland, Hong Kong, Japan, Korea, and Singapore, which intended strong emphasis on both of the higher PE, less than a quarter of teachers reported covering these frequently – in every or almost every lesson.

When teachers’ emphasis across the three types of PE is compared, in Finland, Hong Kong, Korea, and Singapore considerably more teachers made a stronger emphasis on the first and more basic PE, in spite of intended emphasis being the same for the three. Furthermore, in Iran, where less emphasis was prescribed on *reasoning mathematically* than the other two PE, it was this more demanding PE that more teachers reported making emphasis on. In general, as in the case of content, teachers did not appear to be consistent with curricular intentions in their emphasis on PE.
4.2.4. Intended and enacted instructional time

The comparison of mathematics intended and enacted IT was made using the percentage of yearly mathematics IT out of the total IT in the school year as the indicator. The percentage of IT prescribed for teaching mathematics in the 8th grade and the percentage actually employed in teaching the subject, according to teacher reports, were compared. Table 4.4 shows these two statistics for each country and territory. Given the low number of countries, differences between the groups are not significant or conclusive. However, they are relevant in discussing the variation in IT reported by teachers relative to the intended IT. Although the means for the percentage of IT for the two groups (13.24 in LP and 12.98 percent in HP) suggest that intentions for hours to be devoted to mathematics teaching may have been similar across groups, there was more variation in low performers (range for LP = 7; range for HP = 5.7). In spite of the variation in both groups, the small differences among countries in both groups are evidence of the isomorphism in overall curricular structures across education systems (McEneaney and Meyer 2000). Findings also show a slightly lower percentage of total IT devoted to mathematics to that identified in Benavot’s (2004) study of IT in education systems across the world in the 2000 and 1980 decades; in the first, the mean percentage of IT was 13.9 while in the latter the percentage was 13.3.

To compare intentions and enactment, the median and distribution (variance and standard deviation) of the percentage of time employed for mathematics instruction were examined in relation to the intended percentage of time given by curriculum experts in each country or benchmarking territory. The boxplot in figure 4.19 shows the percentage of time distribution

64 Indonesia did not prescribe a percentage of time for mathematics instruction. Finland prescribed a minimum of lessons for grades 6 – 9, leaving to municipalities the decision of how to structure those lessons throughout these four years and whether to increase the number of hours. For the United States the percentage of instructional time devoted to mathematics varied by school district, as did the length of the school year and the school day. For these countries intended IT was not reported.
alongside the mentioned intended percentage. In both groups, when looking at the median of teachers’ reported mathematics IT and the intended percentage, some of the countries appeared to be in correspondence. However, as the findings presented previously on yearly hours of IT indicated, the variation in the percentage of total time devoted to teaching mathematics was wider in low performers than in high performers. Specifically, in low performing Iran, Chile, Turkey, Thailand, Lebanon, and Ukraine the intended percentage of hours for mathematics instruction was close to the median and mean percentage of actual time distribution. However, Iran, Turkey and Ukraine show more variation in enacted IT (Var = 19.44, 22.68, and 18.48, respectively). Morocco, Norway, and Romania are countries where the percentage of mathematics IT differed most from intentions and had wider variation (Var = 16.56, 25.6 and 17.46, respectively).65

The average variance of the percentage of actual mathematics IT for low performing countries is 20.64; in contrast, the average variance for all high performers is 11.81. High performers Japan, Singapore, Hong Kong, Russian Federation and Slovenia stand out for their median being close to the intended percentage of IT. Japan, in particular, with a variance of 2.67, is the country where teachers were more closely in correspondence with national prescriptions. On the other hand, teachers’ reported percentage of IT in Korea and Chinese Taipei corresponded less with prescribed IT. In Korea, the median (12.41) and the mean (13.84) for the percentage of actual teaching time were both higher than the intended time (11.76), indicating that the majority of teachers devoted more time to mathematics than they should according to the national curriculum. The same occurred in Chinese Taipei, where the mean and the median were

65 In Morocco, the prescribed percentage of hours appears above actual instructional time for the majority of teachers (median = 11.11). On the other hand, in Norway and Romania, the medians indicate that the majority of teachers employed a higher percentage of instructional time to mathematics than that which is intended.
also higher (median = 14.29 and mean = 14.57) than the intended percentage of time for teaching mathematics (12.50), although there was less variation (variance = 6.85).

These findings confirm the suggested hypothesis for earlier findings; the IT element of OTL is more closely followed by teachers in high performers than in low performers. This may be indicative of teachers’ lack of guidance regarding the mathematics curriculum in low performers; it may also be an indication of the more varied classroom student composition and school needs, to which teachers, as decision makers, must adjust in order to cover the curriculum or to attend other more pressing needs, for example.

4.3. Summary and conclusions on OTL the Mathematics Curriculum

The opportunities that teachers provided students to learn mathematics identified in TIMSS 2011 data show differences between low and high performing countries and territories and variation within the two groups. Differences in the intended mathematics curriculum up to the 8th grade or equivalent of formal schooling were much less pronounced between the two groups of countries and territories, even when the moment in the schooling progression when more advanced topics were introduced varied; in general, more advanced topics seemed to enter the intended curriculum sooner in high performing countries or territories.

In contrast to what was hypothesized, the comparison of the two levels of the curriculum showed that content topics, PE, and IT were defined by most teachers during instruction in ways that differ considerably from curricular intentions in both low and high performers. However, a higher degree of correspondence between intentions and enactment was seen in some high performers for content topics and IT.
These findings provide further evidence of the gap that exists between intentions and enactment, problematized under the fidelity point of view of implementation, examined or adopted by earlier as well as more recent studies (see Fullan and Promfet 1977; Polikoff 2012; Roach et al 2008; Snyder et al. 1992; Vos and Bos 2005). They also raise further questions considering that the gap exists to an important extent in countries that consistently perform well above average in international assessments. Admittedly, the divergence is problematic inasmuch as the objectives prescribed in curricular policy are not achieved. However, such divergence does not appear to hinder student high achievement in general. Overall, the variation across countries and within countries for these four elements of OTL supports the idea of teachers as curriculum enactors, which assumes teachers as decision making agents influenced by multiple factors exercising a degree of autonomy.

Specific findings are consistent with previous studies on the mathematics curriculum for content topics, which is not the case for PE. More advanced topics, specifically algebra, geometry and data, were intended to be introduced in both groups prior to 8th grade, and more so in high performers. But teachers’ actual coverage of these intended algebra topics was more consistent in high performers than low performers. In addition, number – or arithmetic – topics continue to be predominant during grade 8 in many classrooms in the low performing group.

Findings for IT indicate that, on average, teachers in low performing countries devoted more time to the teaching of mathematics, although there was higher within country variation in the amount of time teachers devoted to the task. Earlier studies that examine the association of IT and achievement through textbook space, curricular documents or teacher reports claim that IT is significantly associated with student achievement (Anderson 1994; Millot 1995; Schmidt et al. 2001). More recent studies narrow such association to the time teachers spend on activities that
engage students in learning, i.e. time on task or engaged learning time (Benavot 2004; Fisher and Berliner 1985). It can be hypothesized, then, that time in many low performing country classrooms is used to teach topics that were not mastered by students or the less complex content topics, given the restraints and demands related to students’ prior knowledge, school context, or teacher factors that are likely to exist in these contexts.

Furthermore, findings in relation to content topics covered during the 8th grade show that teachers in low performing countries continue teaching number topics, in spite of their exclusion from curricular intentions at this grade level. These results are more than likely evidence of the lack of previous knowledge of number topics that students bring to the 8th grade, despite their inclusion in curricular intentions across several grades. In order to teach other intended content areas, such as algebra and geometry, for which knowledge of basic arithmetic topics is necessary, teachers decide to first teach this basic arithmetic content. This possibility implies teachers making decisions about the curriculum they can cover, responding to students’ learning needs, a finding that would support the existence of teacher autonomy and professional decision-making even in low performing countries.

Another possibility for these findings could be found in the content of the textbooks that teachers follow; when textbook content diverges from curricular instructions, teachers that rely on these tools will not correspond to such intentions. This possibility could be explored through an analysis of alignment between textbooks and curricular policy for 8th grade or equivalent. Finally, although teachers in low performers have or take more time to teach mathematics during 8th grade, perhaps only a fraction of this time is used to teach the topics actually intended for the year. Such conclusion has implications for the learning progress students can make during the year and the advancement into other mathematics content.
Findings on teachers work with low and high demanding PE contradict the hypothesis posited for the study as well as previous studies’ findings. More teachers in low performing countries reported covering HDPE frequently than teachers in the high performing group. Moreover, in high performing countries or territories a higher percentage of teachers reported using LDPE with the highest frequency than the percentage of teachers that reported using HDPE in this category. These findings raise questions in relation to the interpretation, understanding and enacting of the mathematics intended curriculum by teachers in low performers. As part of the literature that examines the reasons why teachers’ instructional decisions diverge from the intended curriculum suggests, policies can be interpreted and understood by enactors in ways that diverge from the actual meanings, and enact it according to their own understandings, which, in turn, derive from their own knowledge and experience.

There is also the possibility that, although teachers understand the policies’ actual intent and meaning, they are not capable of acting on them, because they do not have the knowledge or understanding of how these intentions can be enacted in their teaching practice. Another explanation for these findings could be attributed to measurement error; that is, the questions that intend to capture teachers’ teaching practices are poorly understood by teachers in low performers or do not accurately account for teachers’ actual practices. Furthermore, given the emphasis on teaching cognitive challenging thinking abilities made in curricular policy discourse and in actual curricular intentions, teachers may provide what they believe to be expected responses to survey questions. These possibilities are discussed further in the conclusions chapter.
Figure 4.1. Percentage of teachers that taught mathematics content topics in the high and the low performing groups of countries during or before 8th grade.

Figure 4.2. Percentage of teachers reporting content topics taught during or before 8th grade in low and high performing countries.

Figure 4.3. Percentage of teachers that reported covering low and high demanding performance expectations

## Figure 4.4. Percentage of students exposed to traditional and challenging instructional strategies


<table>
<thead>
<tr>
<th>Country</th>
<th>Almost never or never</th>
<th>Some lessons on average</th>
<th>About half the lessons</th>
<th>Every or almost every lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iran, Islamic</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lebanon</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morocco</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Romania</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turkey</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ukraine</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group composite</strong></td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese, Taipei</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong, SAR</td>
<td>HCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Korea, Republic of</td>
<td>HCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russian Federation</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slovenia</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>LCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group composite</strong></td>
<td>HCIS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 25%: Light green
- 50%: Green
- 50%: Light blue
- 100%: Dark blue

25% 50% 50% 100%
Figure 4.5. Mathematics yearly instructional time in low and high performing countries

Figure 4.6. Mathematics yearly instructional time by country

Table 4.1. Descriptive statistics for instructional time by content area during the 8th grade or equivalent.

<table>
<thead>
<tr>
<th>Content area</th>
<th>Mean</th>
<th>Std. Error of Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Std. Deviation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time spent on teaching number topics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low performers</td>
<td>23.14</td>
<td>.283</td>
<td>20.00</td>
<td>20</td>
<td>12.394</td>
<td>153.600</td>
</tr>
<tr>
<td>High performers</td>
<td>20.45</td>
<td>.290</td>
<td>20.00</td>
<td>10</td>
<td>14.359</td>
<td>206.167</td>
</tr>
<tr>
<td>Time spent on teaching algebra topics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low performers</td>
<td>26.16</td>
<td>.236</td>
<td>25.00</td>
<td>20</td>
<td>10.371</td>
<td>107.557</td>
</tr>
<tr>
<td>High performers</td>
<td>34.56</td>
<td>.351</td>
<td>30.00</td>
<td>30</td>
<td>17.378</td>
<td>301.982</td>
</tr>
<tr>
<td>Time spent on teaching geometry topics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low performers</td>
<td>28.93</td>
<td>.261</td>
<td>30.00</td>
<td>30</td>
<td>11.473</td>
<td>131.619</td>
</tr>
<tr>
<td>High performers</td>
<td>25.05</td>
<td>.302</td>
<td>25.00</td>
<td>30</td>
<td>14.965</td>
<td>223.948</td>
</tr>
<tr>
<td>Time spent on teaching data topics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low performers</td>
<td>10.86</td>
<td>.174</td>
<td>10.00</td>
<td>10</td>
<td>7.621</td>
<td>58.080</td>
</tr>
<tr>
<td>High performers</td>
<td>9.62</td>
<td>.171</td>
<td>10.00</td>
<td>10</td>
<td>8.466</td>
<td>71.673</td>
</tr>
</tbody>
</table>

Figure 4.7. Percentage of time spent teaching number topics by country

Figure 4.8. Percentage of time spent teaching algebra topics

Figure 4.9. Percentage of time spent teaching geometry topics

Figure 4.10. Percentage of time spent teaching data topics during the 8th grade

### Table 4.2. Countries intending content topics to be taught

<table>
<thead>
<tr>
<th>Topics</th>
<th>Low performing countries (10)</th>
<th>High performing countries or territory (9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Countries intending coverage during or before 8th grade</td>
<td>Intended to be taught during 8th grade</td>
</tr>
<tr>
<td>Number</td>
<td>Countries intending coverage during or before 8th grade</td>
<td>Intended to be taught during 8th grade</td>
</tr>
<tr>
<td>Computing, estimating, or approximating</td>
<td>10 8 2 7</td>
<td>9 7 2 9</td>
</tr>
<tr>
<td>Concepts and computing with fractions</td>
<td>10 7 3 7</td>
<td>9 7 2 7</td>
</tr>
<tr>
<td>Concepts and computing with decimals</td>
<td>10 5 5 6</td>
<td>9 6 3 5</td>
</tr>
<tr>
<td>Representing, comparing, ordering, comp.</td>
<td>10 5 5 6</td>
<td>9 6 3 5</td>
</tr>
<tr>
<td>Problem solving - percents &amp; proportions</td>
<td>10 5 1 4</td>
<td>9 5 4 4</td>
</tr>
<tr>
<td>Algebra</td>
<td>9 5 4 1 8</td>
<td>7 2 1 4 2 6</td>
</tr>
<tr>
<td>Numeric, algebraic, &amp; geometric patterns</td>
<td>8 2 6 2 7</td>
<td>9 1 8 6</td>
</tr>
<tr>
<td>Simplifying &amp; evaluating algebraic exp.</td>
<td>8 1 2 5 2 6</td>
<td>9 2 1 6 6</td>
</tr>
<tr>
<td>Simple linear equations and inequalities</td>
<td>8 1 3 1 5 3</td>
<td>8 1 5 2 1 4</td>
</tr>
<tr>
<td>Simultaneous (two variables) equations</td>
<td>5 1 3 1 5 3</td>
<td>8 1 5 2 1 4</td>
</tr>
<tr>
<td>Representation of functions</td>
<td>6 3 3 4 6</td>
<td>9 2 2 5 6</td>
</tr>
<tr>
<td>Geometry</td>
<td>10 7 3 6</td>
<td>8 2 6 1 6</td>
</tr>
<tr>
<td>Geometric properties - angles &amp; shapes</td>
<td>7 3 3 1 3 5</td>
<td>9 3 6 8</td>
</tr>
<tr>
<td>Congruent figures and similar triangles</td>
<td>5 2 1 2 5 5</td>
<td>8 4 4 1 6</td>
</tr>
<tr>
<td>Relationship: 3D shapes &amp; their 2D rep.</td>
<td>8 1 1 6 2 7</td>
<td>8 2 6 1 8</td>
</tr>
<tr>
<td>Using measurement formulas: p, c, a, &amp; v</td>
<td>8 1 1 6 2 7</td>
<td>9 3 6 6</td>
</tr>
<tr>
<td>Points on the Cartesian plane</td>
<td>8 1 1 6 2 7</td>
<td>9 3 6 6</td>
</tr>
<tr>
<td>Translation, reflection, and rotation</td>
<td>7 1 4 2 3 5</td>
<td>7 2 1 4 2 5</td>
</tr>
<tr>
<td>Data</td>
<td>8 5 3 2 5</td>
<td>9 5 4 7</td>
</tr>
<tr>
<td>Reading &amp; displaying data</td>
<td>8 3 5 2 5</td>
<td>6 1 5 3 8</td>
</tr>
<tr>
<td>Interpreting data sets (e.g., predict)</td>
<td>7 1 1 5 3 6</td>
<td>4 2 2 5 5</td>
</tr>
<tr>
<td>Judging, predicting, &amp; determining chances</td>
<td>7 1 1 5 3 6</td>
<td>4 2 2 5 5</td>
</tr>
</tbody>
</table>

Figure 4.11. Topics in country/territory curricular intentions and percentage of students taught topics during 8th grade

### Low Performers

<table>
<thead>
<tr>
<th>Country curriculum coverage</th>
<th>Percentage of teachers that reported coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computing, estimating, or approximating</td>
<td></td>
</tr>
<tr>
<td>Concepts and computing with fractions</td>
<td></td>
</tr>
<tr>
<td>Concepts and computing with decimals</td>
<td></td>
</tr>
<tr>
<td>Representing, comparing, ordering, comp.</td>
<td></td>
</tr>
<tr>
<td>Problem solving - percents &amp; proportions</td>
<td></td>
</tr>
<tr>
<td>Numerical, algebraic, &amp; geometric patterns</td>
<td></td>
</tr>
<tr>
<td>Simplifying &amp; evaluating algebraic expressions</td>
<td></td>
</tr>
<tr>
<td>Simple linear equations and inequalities</td>
<td></td>
</tr>
<tr>
<td>Simultaneous (two variables) equations</td>
<td></td>
</tr>
<tr>
<td>Representation of functions</td>
<td></td>
</tr>
<tr>
<td>Geometric properties - angles &amp; shapes</td>
<td></td>
</tr>
<tr>
<td>Congruent figures and similar triangles</td>
<td></td>
</tr>
<tr>
<td>Relationship: 3D shapes &amp; their 2D rep.</td>
<td></td>
</tr>
<tr>
<td>Using measurement formulas: p, c, a, v</td>
<td></td>
</tr>
<tr>
<td>Points on the Cartesian plane</td>
<td></td>
</tr>
<tr>
<td>Translation, reflection, and rotation</td>
<td></td>
</tr>
<tr>
<td>Reading &amp; displaying data</td>
<td></td>
</tr>
<tr>
<td>Interpreting data sets (e.g., predict)</td>
<td></td>
</tr>
<tr>
<td>Judging, predicting, &amp; determining chances</td>
<td></td>
</tr>
</tbody>
</table>

### CHILE

<table>
<thead>
<tr>
<th>Country curriculum coverage</th>
<th>Percentage of teachers that reported coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computing, estimating, or approximating</td>
<td></td>
</tr>
<tr>
<td>Concepts and computing with fractions</td>
<td></td>
</tr>
<tr>
<td>Concepts and computing with decimals</td>
<td></td>
</tr>
<tr>
<td>Representing, comparing, ordering, comp.</td>
<td></td>
</tr>
<tr>
<td>Problem solving - percents &amp; proportions</td>
<td></td>
</tr>
<tr>
<td>Numerical, algebraic, &amp; geometric patterns</td>
<td></td>
</tr>
<tr>
<td>Simplifying &amp; evaluating algebraic expressions</td>
<td></td>
</tr>
<tr>
<td>Simple linear equations and inequalities</td>
<td></td>
</tr>
<tr>
<td>Simultaneous (two variables) equations</td>
<td></td>
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<tr>
<td>Representation of functions</td>
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<tr>
<td>Geometric properties - angles &amp; shapes</td>
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</tr>
<tr>
<td>Congruent figures and similar triangles</td>
<td></td>
</tr>
<tr>
<td>Relationship: 3D shapes &amp; their 2D rep.</td>
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</tr>
<tr>
<td>Using measurement formulas: p, c, a, v</td>
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</tr>
<tr>
<td>Points on the Cartesian plane</td>
<td></td>
</tr>
<tr>
<td>Translation, reflection, and rotation</td>
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</tr>
<tr>
<td>Reading &amp; displaying data</td>
<td></td>
</tr>
<tr>
<td>Interpreting data sets (e.g., predict)</td>
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</tr>
<tr>
<td>Judging, predicting, &amp; determining chances</td>
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</tr>
</tbody>
</table>

### INDONESIA

<table>
<thead>
<tr>
<th>Country curriculum coverage</th>
<th>Percentage of teachers that reported coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computing, estimating, or approximating</td>
<td></td>
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<tr>
<td>Concepts and computing with fractions</td>
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<tr>
<td>Concepts and computing with decimals</td>
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</tr>
<tr>
<td>Representing, comparing, ordering, comp.</td>
<td></td>
</tr>
<tr>
<td>Problem solving - percents &amp; proportions</td>
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<td>Numerical, algebraic, &amp; geometric patterns</td>
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<td>Simple linear equations and inequalities</td>
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<td>Simultaneous (two variables) equations</td>
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</tr>
<tr>
<td>Representation of functions</td>
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<tr>
<td>Geometric properties - angles &amp; shapes</td>
<td></td>
</tr>
<tr>
<td>Congruent figures and similar triangles</td>
<td></td>
</tr>
<tr>
<td>Relationship: 3D shapes &amp; their 2D rep.</td>
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### IRAN, ISLAMIC REPUBLIC OF

<table>
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<tr>
<th>Country curriculum coverage</th>
<th>Percentage of teachers that reported coverage</th>
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<td>Geometric properties - angles &amp; shapes</td>
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<td>Judging, predicting, &amp; determining chances</td>
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</table>

About 90% of students intended to be taught on average across countries. About 10% of the students intended to be taught on average across country group.

Not intended to be taught.

Figure 4.12. Topics in country/territory curricular intentions and percentage of students taught topics during or before 8th grade.

### Figure 4.13. Topics in country/territory curricular intentions and percentage of students taught topics during or before 8th grade


<table>
<thead>
<tr>
<th>MOROCCO</th>
<th>NORWAY</th>
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<th>THAILAND</th>
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<td><strong>Country curriculum coverage</strong></td>
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</tr>
</tbody>
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**About 90% of students intended to be taught on average across countries**

**About 10% of the students intended to be taught on average across country group**

**Not intended to be taught**

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*Note: The table above shows the percentage of teachers that reported coverage for various topics in the curriculum.*

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Figure 4.14. Topics in country/territory curricular intentions and percentage of students taught topics during or before 8th grade

Figure 4.15. Topics in country/territory curricular intentions and percentage of students taught topics during or before 8th grade

Figure 4.16. Topics in country/territory curricular intentions and percentage of students taught topics during or before 8th grade

Figure 4.17. Percentage of curriculum coverage for some content topics at the intended and enacted level.

Figure 4.18. Emphasis intended in national/local curriculum and actual coverage reported by teachers on performance expectations.

Table 4.3. Percentage of total instructional time intended and actually devoted to mathematics instruction during 8th grade of schooling.

<table>
<thead>
<tr>
<th>Low performing countries</th>
<th>Intended percentage of math instruction</th>
<th>Percentage of total time actually devoted to math instruction</th>
<th>Hours actually devoted devoted to math instruction</th>
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<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Range</td>
<td>Variance</td>
</tr>
<tr>
<td>Chile</td>
<td>15.00</td>
<td>15.00</td>
<td>23.04</td>
</tr>
<tr>
<td>Indonesia</td>
<td>12.50</td>
<td>28.13</td>
<td>39.29</td>
</tr>
<tr>
<td>Iran, Islamic Republic of Lebanon</td>
<td>12.05</td>
<td>30.09</td>
<td>19.44</td>
</tr>
<tr>
<td>Morocco</td>
<td>17.00</td>
<td>25.76</td>
<td>10.04</td>
</tr>
<tr>
<td>Norway</td>
<td>12.90</td>
<td>11.11</td>
<td>15.56</td>
</tr>
<tr>
<td>Romania</td>
<td>10.00</td>
<td>32.67</td>
<td>13.63</td>
</tr>
<tr>
<td>Thailand</td>
<td>10.00</td>
<td>30.60</td>
<td>17.46</td>
</tr>
<tr>
<td>Turkey</td>
<td>14.30</td>
<td>21.67</td>
<td>22.68</td>
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<tr>
<td>Ukraine</td>
<td>14.00</td>
<td>34.95</td>
<td>18.475</td>
</tr>
</tbody>
</table>

Group mean

**Low performing countries**

- Median 13.24
- Range 20.64
- Variance 14.04
- Mean 291.13
- Median 12.5
- Range 225.92
- Variance 18.39

**High performing countries/territories**

- Median 15.29
- Range 11.87
- Variance 11.87
- Mean 365.333
- Median 17.36
- Range 934.7
- Variance 187.5

**Group mean**

- Median 12.98
- Range 11.81
- Variance 13.63
- Mean 231.350
- Median 168.521
- Range 135.938

Figure 4.19. Percentage of instructional time intended for mathematics teaching and distribution of actual mathematics instructional time.

Chapter 5. INFLUENCES ON THE ENACTED CURRICULUM

Findings in Chapter IV depict opportunities to learn mathematics provided by teachers during the 8th grade or prior, across low and high performing countries. Considerable differences were found between the low and high performing group in the extent to which teachers cover mathematics topics in the eighth grade; however, there were more similarities in relation to the intended mathematics curriculum across countries. Furthermore, the comparison of curricular intentions and enactment by country corroborates the existence of a gap between these two curricular dimensions, highlighted as problematic in discussions of curriculum and learning, and discussed in this study as a result of context factors and a degree of teacher autonomy.

Differences in coverage also stand out by content area. Lower percentages of teachers in low performing countries reported covering intended topics in algebra and geometry. As expected, number topics were extensively covered in all countries by the 8th grade, whereas the more advanced topics in the other three areas were covered less extensively, especially in the low performing group.

The findings in relation to the teaching of these content topics accompanied by more or less cognitively challenging processes, or PE, were unexpected. More teachers in low performing countries reported covering the higher order PE than teachers in the high performing group, where the majority of countries had more than 50% of their teachers reporting covering these types of PE in only some of the lessons. This is particularly interesting given that a strong emphasis on the more demanding PE was prescribed in curricular intentions of more high-performing countries or territories. Notably, it was high performers’ teachers who also made a
stronger emphasis on the more basic PE. Similar to enacted PE, the use of IS categorized as more challenging were reported as covered more consistently by teachers in low performing countries.

Finally, findings in instructional time devoted to mathematics also revealed differences between the two groups. Teachers in low performing countries displayed wider variation in the amount of IT reported for teaching mathematics. In addition, when comparing IT reported by teachers to the intended IT by country, teachers in high performing countries appeared to be closer in line to IT intentions. And whereas teachers in low performers on average spent more time than high performers on number topics during the 8th grade, teachers in high performers devoted more time on average to the teaching of algebra topics.

As predicted, these analyses of OTL in nineteen TIMSS participating countries and territories show variation within each group – low and high performing –, but they also show some distinct patterns within them. They confirm a divergence from intentions and variation in teachers’ decision making in enacting the mathematics curriculum in both low and high performers, a finding that questions the need for strict alignment.

The patterns and differences identified between the two groups suggest that different factors shape teachers’ decisions across countries, possibly having varying degrees of influence on teachers’ instructional decisions. It can be argued, given the variation in the OTL found in the first part of the analyses, that factors that are closer to the teaching context are those that exert a stronger influence, including teacher factors. This chapter covers the questions of this study that intend to explore the influence of two types of factors on OTL: system factors (teacher collaboration, teacher evaluation, and the use of textbooks), which are captured through teacher and national reports, and teacher factors (teacher preparation, professional development, experience and perceived subject matter knowledge), which are gathered through teacher reports.
Before the analysis of each of these factors in relation to OTL, a description and comparison was made of the curricular governance systems across low and high performers, according to the information given by the TIMSS expert national reports. The elements observed of the curricular governance system include the existence of a national curriculum, teacher education, professional development and evaluation policies (Mullis et al. 2009). These descriptive analyses also provide an indication of the convergence of policies across countries. To complement the characterization of the systems, a comparison was made of policies at the implementation level, along with the individual teacher factors for each group and across countries.

Following this discussion, and responding to the research questions regarding the influence of factors on OTL, the results of the bivariate analysis of selected system and teacher factors, on one side, and OTL, on the other, are presented, comparing findings between the two groups. Finally, a summary of these findings is made to conclude this chapter.

5.1. The Curricular governance system in low and high performers

The curricular governance systems across countries were examined through the policies established relative to the teaching of the curriculum, including curricular reform, teacher preparation, induction, and training policies. As discussed in the literature, these policies intend to direct or regulate teachers’ instruction and therefore ensure planned learning and educational outcomes (Gvirtz and Beech 2004); accordingly, the assumption is that the inclusion of more of these policy instruments characterizes a highly directive or regulatory curricular governance system. Teacher preparation programs, qualifying examinations or certifications, and mandatory

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66 These national policies were obtained from expert responses in each country through the curriculum questionnaire information.
textbooks, for example, have the additional intent of transmitting curricular policy to teachers. Such a system would arguably translate into higher levels of correspondence between intentions and enactment.

This analysis compared policies between low and high performers, as well as across countries and identified differences and tendencies. It was expected to find a certain degree of convergence in policies across countries given the discussed policy environment in which policies become popular ‘best policy solutions’ to education problems. This analysis confirmed such hypothesis.67 Tables 5.1 and 5.2 show the curricular and teacher policies adopted in each country.

In relation to the curriculum, all countries, except for Iran, reported having a national curriculum that covered mathematics instruction through and for grade 8. Hong Kong and Finland stand out in that they recommended a core curriculum or syllabus that schools or municipalities could adapt, while the rest of the countries appeared to mandate the curriculum with little room for adaptation. In the most countries in both groups, such curriculum was introduced within eight years prior to the study (2011) (8 low performers and 5 high performers), while 3 (Chile, Thailand and Turkey) and 2 (Japan and Singapore) low and high performers, respectively, introduced such curriculum within the three previous years to the study. The rest of the countries or territories—reported teaching with a curriculum that is 9 years or older. In addition, several countries, including some that had recently reformed their mathematics curriculum, reported, at the time of the study, being in a revision of the mathematics curriculum.

Moreover, indicators of the degree to which curricular policy intends to direct or control teachers’ instruction showed variation across countries, but commonalities between the two

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67 The U.S., as a decentralized system, reports variation by states in all policies; therefore, it is not included in the conclusions drawn in this section.
groups. In all countries, the curriculum prescribed at least goals and objectives, while 7 of the 10 low performers and 6 of 9 high performers also prescribed instructional processes or methods; in addition, 8 and 6 low and high performers, respectively, also prescribed assessment methods or activities. Chinese Taipei, Hong Kong, Korea, and Singapore (all Asian high performers), and Iran, Lebanon, Morocco, Romania, Thailand, and Turkey showed being more directive in their curricular policy, prescribing, besides curricular content, goals and objectives, instructional processes or methods, materials, and assessment methods or activities. Those with less nationally established directional measures in the two groups were Russian Federation, the United States, Chile, and Indonesia, which prescribed, besides curricular content, mainly goals and objectives.

High-stakes testing has clearly permeated across countries. According to national responses to the eighth grade curriculum questionnaire, in all low and high performers, an educational authority administered examinations in mathematics that have consequences for individual students, such as entry to a higher school system or university, exiting or graduating from secondary school, except the United States, where each state could adopt different measures. The inclusion of a process for approving mathematics textbooks was found common across the majority of countries, with the exception of high performing Finland and low performing Norway.

The requirements set by ministries of education for 8th grade teachers, in general, were similar across countries. A university degree or a four-year teachers college program was reported as the minimum requirement to teach at the eighth grade in all countries. Finland in the high performers required a master’s degree, while university graduates in Singapore obtained a one or two-year postgraduate diploma in education. In the United States the requirements were set by the states. According to the country report, most teachers received their education through
a university degree program in education; candidates with degree in other areas may become certified to teach through an alternative teacher certification program. In the group of low performers, Iran reported as its requirements for mathematics teachers, in addition to an education degree, the completion of a mathematics education program. Romania, where teachers were required a degree in the subject they teach, reported also requiring teachers to take additional pedagogical training and a supervised practicum. Most countries said teachers were trained in teacher education colleges or universities.

Differences were found in the characteristics of teacher preparation programs between low and high performers, however few and not conclusive given the small amount of countries being examined. In all high performers, a supervised practicum was required, while two of the low performers (Iran and Lebanon) did not have such requirement. In addition, with the exception of Finland that required a masters’ degree, all high performers required of teachers a qualifying examination or certification, while only 6 of 10 low performers did so. A probationary teaching period appeared to be a less popular policy, but more common in high performers, where 4 of 10 countries/territories had adopted it, in comparison to 2 of 10 low performers. Similarly, the requirement to complete a mentoring or induction period was also a more common measure among high performers, where 6 of 9 employed it, in comparison to 4 of 10 low performers. The results of this analysis are consistent with Blomeke’s (2012) findings: a high level of homogeneity across teacher education programs as well as heterogeneity in the type of knowledge these programs give the most attention to.

Given the assumption that countries establish a higher number of policy instruments in order to exert more control over the enacted curriculum, this review of curricular and teacher policies suggests that both low and high performers intend to establish a strong degree of
Clearly, there are differences in educational outcomes among countries that have adopted policies intended to align teachers’ actions with the curriculum, just as there are among countries that exert lower levels of curricular control.

Nevertheless, the degree to which these policies, which are part of a curricular governance system, are adopted and implemented by the actors involved varied widely across countries. Table 5.3 shows, for each country, the policies adopted by over two thirds of teachers or schools, according to their reports. Once again, variation stands out across all countries in the number and combinations of policy instruments implemented. Notably, the prescription of mechanisms to evaluate teachers’ practice is salient over the prescription of activities focused on professional development in many countries, which denotes a policy emphasis on the measurement of outcomes as a means to improve teaching and learning over policies aimed at preparing teachers for the same end.

Worth highlighting is also the fact that in several low performers, as well as in some high performers, many of the policy instruments were extensively followed. Indonesia, Romania, Thailand, and Ukraine, as well as Hong Kong, Russian Federation and the United States are examples. On the other hand, in few countries, both low and high performers, only a couple of instruments were broadly applied; such is the case of Chile (observations by the principal or senior staff and evaluation through student achievement), Norway (the use of textbooks as the basis for instruction and evaluation through student achievement), Chinese Taipei (participation in professional development in mathematics content, the use of textbooks as the basis for instruction and evaluation through student achievement), and Finland (the use of textbooks as the

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68 Chinese Taipei, Hong Kong, Japan, Korea, Russian Federation, Singapore, and Slovenia in high performers, and Morocco, Romania, Turkey and Ukraine in low performers fit into this description.
basis for instruction and evaluation through student achievement). Notably, the use of textbooks as a basis for instruction and evaluation through student achievement, an older and a relatively more recent policy instrument, were reported across most countries.

Overall, this review of curricular governance policies across countries depicts a convergence and growing isomorphism across education systems, as neoinstitutionalists have pointed out (see McEneaney and Meyer 2000; Meyer and Rowan 2006). Contrary to what may be expected given the belief that many of these policies are recipes for improved outcomes, low performers, often also developing countries, are also closely following policy world change. Nevertheless, such change has not translated into higher achievement, which questions policies believed effects. The specific analysis of these policy instruments and their adoption at the school and classroom level, according to school or teacher questionnaires, is presented in the following section.

5.2. Curricular policies and teacher characteristics

Teacher collaboration. I recognize that although teacher collaboration reported by teachers may likely be the result of country policies that mandate or promote some form of collaboration, it may also be the result of schools’ organizational climate. Figure 5.1 shows the percentage of teachers that reported collaborating more or less frequently. Although chi-square test indicated a significant difference in teachers reports between the low and high performing group, $X^2 (2) = 10.46$, $p<.05$, standardized residuals as well as Cramer’s statistic indicated very weak or almost inexistent effects. When looking across countries (see figure 5.2), only some

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69 That some of these instruments are not listed in some countries does not mean that they do not intend them as policies; they could be established, but not followed by a broad majority of teachers or schools.

70 Curriculum questionnaire did not provide information on teacher collaboration policies.
variation was seen. Notably, Indonesia, Lebanon, Romania and Slovenia are countries where more teachers reported being very collaborative (close to 40% or more).

**Textbooks.** Figure 5.3 illustrates the uses that were given to textbooks by teachers in each group of countries or territories. According to the Pearson chi-square test, the difference in textbook use between low and high performers is statistically significant, \(X^2 (2) = 27.543, p<.001\). Standardized residuals show that significantly more teachers used textbooks as a supplement in low performing countries (z=3.4). Although standardized residuals show that the use of textbooks as a basis for instruction was not significantly different across the two groups, the percentage of teachers that reported such in high performers was higher – 78% compared to 72% in low performers.

Figure 5.4 shows the percentage of teachers according to the different uses given to textbooks by country or territory. In most of these, both low and high performers, textbooks appear to have been used as a basis for instruction by most teachers. Hence, the importance textbooks continue to have in teachers enacting of the curriculum, in spite of the incorporation of other technologies in the classroom. Furthermore, in Chile, with 75% and to a lesser extent Morocco, the United States, and Singapore, with 50, 44, and 37%, respectively, textbooks were used only as a supplement by more teachers than in all others.

**Evaluation.** Information about the evaluation of mathematics’ teachers practice was gathered through the school questionnaire regarding the following activities: observations by the principal or senior staff, observations by inspectors or other persons external to the school, evaluation through student achievement, and teacher peer review. In this study these activities are considered to be likely the result of policies set in place by the country or territory to
supervise teachers’ performance. Being reported by the schools participating in the study,\footnote{The unit of analysis continues to be the teacher. However, the occurrence of evaluation of teachers’ practice is reported by the school they teach and for which they also report.} we know that these were policies that were being implemented to some degree.

Figure 5.5 shows the percentage of schools that reported performing each kind of evaluation. Differences between the two groups of countries in regards to evaluation were significant for the following types of evaluation: observations by the principal or senior staff, $X^2 (1) = 11.88, p<.05$, which were higher in high performing countries or territories; observations by inspectors or other persons external to the school, $X^2 (1) = 358.45, p<.001$, which, in contrast, occurred much more in low performing countries (65% and 36%); and evaluation through student achievement $X^2 (1) = 41.89, p<.001$, which occurred to a higher extent in low performing countries (93% and 87%). Evaluation of teacher practice through observations by the principal or senior staff and student achievement are the two forms of evaluation performed to a higher extent in both low and high performers.

Figures 5.6 and 5.7 show the evaluation reported by surveyed schools in each country. Notably, more than 80% of these schools in all low performing countries employed evaluation of teacher practice through student achievement, which some scholarship argues has adverse effects on teachers’ practice (Hamilton and Berends 2006; Gunzenhauser 2003; Palmer and Snodgrass 2011). Observations by principals or senior staff in the school were the second form of evaluation more widely used in low performers, adopted by more than 80% of schools in all countries except for Morocco and Norway. In high performing countries observations by staff were reported by the vast majority of schools in nearly all countries, the exception being Chinese Taipei and Finland. Contrary to low performers, evaluation of teacher practice through student assessment was not reported to such high extent in all high performers. In Chinese Taipei,
Finland, and Japan less than 80% of schools reported using this form of evaluation. In addition, in high performing Korea and Russian federation, and in low performing Ukraine, evaluation through teacher peer review is reported by close to 100% of surveyed schools.

**Teacher education.** TIMSS gathers information on teachers’ type of education in relation to whether teachers have a strong content knowledge, pedagogical knowledge with a focus on mathematics, both, or neither. The descriptive statistics across the two groups of countries indicate that there are considerable similarities in the type of education that 8th grade mathematics teachers reported in low and high performers overall, but, as expected, there is some variation across countries or territories. Figure 5.8 shows the statistics for teachers’ education. In both groups, about 32% of teachers reported having a major in mathematics and mathematics education, while 34% in low performing and 37.6% in high performing said they had a major in mathematics but not in mathematics education. Much lower is the percentage of teachers in both groups that reported having a major in mathematics education but not in mathematics – 11.3% for low performers and 15.6% for high performers –, as is the percentage of teachers with other majors – 11.4% and 14.3%, respectively. Pearson’s chi-square test and standardized residuals indicate that in the former, the difference between the groups is significant, $X^2 (4) = 286.15, \ p<.001, \ z=-2.9)$. The most important difference, however, is in the percentage of teachers that did not report having post-secondary education; while in high performers this is .4%, in low performers the percentage of teachers is 11.6% ($z=12.1$).

Some countries in both groups stand out with uncommon proportions in teacher education type (see figure 5.9). Low performers Romania and Turkey stand out for having over 50% of 8th grade teachers (55 and 72%) that reported having a major in both areas: mathematics and mathematics education; practically the rest of the teachers in Romania, 27.4%, have a major
in mathematics but not in mathematics education. Low performing Ukraine stands out as a country where about half of its teachers reported having a major in mathematics but not in mathematics education and close to half have a major in both. In Morocco most teachers reported having no post-secondary education – 78%, which possibly explains an important proportion of the differences between low and high performers for this variable. In low performing Norway, on the other hand, although teachers said they have postsecondary education, close to 50% informed having majors other than mathematics or mathematics education. In the group of high performers, Finland and Korea are the two countries with the lowest percentage – around 7% – of teachers prepared in both mathematics and mathematics education. In Finland and the United States, about a third of teachers said they had other majors, and Finland is the only high performer where over 50% of teachers reported having a major in mathematics but not in mathematics education.

Overall, there are no clear differences in the type of education that teachers in low and high performers acquired, suggesting that changes in teacher education policies are converging across education systems, once again, coinciding with neoinstitutionalists’ claim (McEneaney and Meyer, 2000; Meyer and Rowan 2006). One difference, however, is clear: while nearly all teachers in high performers appear to have post-secondary education, an important percentage of teachers in low performers lack a post-secondary education degree. The change possibly occurs at a slower pace in some countries, given specific characteristics of teaching bodies and the policies that regulate their careers.

**Teacher experience.** Years of experience, which according to the literature is another element that may influence teacher instruction, differed significantly between low and high performers, $X^2 (3) = 23.05, p<.001$, although the differences were not large (see figure 5.10).
The percentage of teachers with more than 20 years of experience was the group with the wider difference (6 percentage points higher in low performers), and it was also the biggest percentage of teachers in both groups (above one third of teachers). Across countries, teachers’ years of experience varied considerably (see figure 5.11). Notably, about 65% of teachers in Morocco, Romania, and Ukraine reported having more than 20 years teaching, as was the case of high performing Russian Federation, where along with low Romania and Ukraine, about only 3% of teachers had been teaching for 5 years or less. On the other hand, Singapore stands out with nearly 50% of teachers with 5 years or less of experience.

**Teachers’ perceived preparedness to teach.** Teachers’ self-reported preparedness to teach was examined for each of the topics in the framework. Figure 5.12 shows the percentage of teachers that reported feeling very well prepared to teach for each group of countries or territories. Notably, in all content topics a higher percentage of teachers in high performers reported feeling very well prepared to teach, although in some cases the difference is small (below 3 percentage points). Nevertheless, for all topics, more than 50% of teachers in both groups of countries reported feeling very well prepared to teach. The content topics with the lower percentage of perceived teacher preparation were *numeric, algebraic and geometric patterns and sequences, relationships between 3-dimensional shapes and their 2-dimensional representations, interpreting data sets, and judging and predicting*, notably some of the more complex topics.

Figure 5.13 shows the percentage of teachers that reported feeling very well prepared to teach, by country or territory. The countries with the lowest percentages of teachers that feel prepared to teach throughout all topics are Indonesia and Thailand in low performers, and, interestingly, Japan in high performers. Worth noting is that Japan, along with other Asian
participants, have consistently had the lowest percentages of students report positive attitudes
toward learning mathematics or being confident in mathematics in TIMSS surveys, a finding that
corresponds with Japanese teachers’ lower levels of confidence.

According to Spillane (2000) and Stein and colleagues (2007), teachers tend to focus their
teaching on the content they know. The results of this analysis, given this claim, could be related
to teacher coverage of the mathematics curriculum; as seen in the analysis of OTL, a percentage
of teachers in low performers fail to provide OTL the more complex content topics.

Professional development. Six types of professional development (PD) activities were
tested in their association to teachers’ instructional decisions: content knowledge, pedagogical,
curriculum development, critical thinking, assessment, and PD to address student needs. The
extent to which these types of PD appeared to be implemented across the two groups of countries
varied little in most cases (see figure 5.14). For content knowledge PD, although Pearson chi-
square test indicates a significant difference in the percentage of teachers participating between
the two groups, $X^2(1) = 9.864$, $p<.05$, the difference is small: 55.1% in low performers and
59.8% in high performers. In the case of pedagogy focused PD, the chi-square test also produced
significant results in the comparison of teachers’ participation between low and high performers,
$X^2 (1) = 13.634$, $p<.001$. However, the difference is not outstanding (57% in low performers and
62.4% in high performers).

A similar situation occurred with PD focused on curriculum development, for which high
performers with 53% participation were 5 percentage points above low performers. The
difference in participation in PD for critical thinking was not significantly different between the
two groups, $X^2 (1) = 3.589$. Notably, in PD for critical thinking, mathematics assessment, and
student needs, participation was lower than in the other types of PD for both groups. Teachers’
participation in PD for mathematics assessment was also significantly different between low and high performers, $X^2 (1) = 6.961, p<.001$, but the difference was also small, with low performers at 47.5%, about four percentage points above high performers. Finally, participation in PD focused on students’ needs was also significantly different between the two groups, $X^2 (1) = 49.236, p<.001$, participation being considerably higher in high performers - 44.9% vs. 34.6% in low performers. Given previous research which to a positive effect of PD focused on content and pedagogical knowledge as well as on curriculum development (Garet et al. 2001; Desimone et al. 2002; Li et al. 2013), these findings highlight the need to evaluate the quality and the extent of teachers’ participation in PD activities.

Figure 5.15 shows the percentage of teachers that reported participation in each type of PD activity by country. Notably, in low performing Norway and Turkey and high performing Finland there was low teacher participation across all types of PD. In contrast, low performing Indonesia, Thailand and Ukraine, and high performing Hong Kong, Russian Federation, Singapore, and the United States reflected important participation (more than 50%) in several of the PD types. In both low and high performers, participation focused mostly in PD for content knowledge and pedagogical aspects of teaching. Professional development for student needs, on the other hand, had the lowest participation in low performers, while in high performers the lowest participation was in PD for critical thinking.

**Schools teachers perceived expectations for student learning.** Teachers’ perceptions about the expectations that teachers in their school had for their students’ achievement were also compared between low and high performers using Pearson Chi-square test. The statistic showed a significant difference in teachers’ perceptions between the two groups, $X^2 (4) = 92.074, p<.001$, shown in Figure 5.16. By about 10 percentage points, more teachers in high performers
perceived that teachers’ expectations for student achievement in their school were high or very high. On the other hand, significantly more teachers in low performers perceived low expectations for student achievement. Nevertheless, the vast majority of teachers in both groups perceived that their peers had medium, high or very high expectations for student achievement.

Teachers’ perceived expectations for student learning vary considerably across countries and territories (see figure 5.17). Indonesia and the United States stand out for the high percentage of teachers that reported perceived high expectations from teachers in their school, while Morocco stands out for the high percentage of teachers that perceived low expectations (more than 20%). Morocco, Turkey, Ukraine, Finland and Russian Federation differed from the rest of the countries in that more teachers reported perceiving medium expectations from teachers in their schools.

5.3. The association between factors and OTL

For the categorical OTL variables (content and performance expectations), the association between OTL and factors was examined using log-linear analysis and Pearson chi-square test, when necessary. Log-linear analyses tested the three-way association among the following: a) mean mathematics performance (low-high performing group); b) teacher or system factor; and c) element of OTL. In other words, log-linear analysis identified differences between low and high performers in the association between a factor and an element of OTL. Table 5.4 shows the statistics of these analyses.

In the case of content topics, the relationship was measured focusing on the 4 content areas – number, algebra, geometry, and data – and looking at the degree of correspondence between intentions and enactment. Each of the four content areas was represented by a variable
with 3 categories. The categories indicate low, medium or high correspondence between intentions and enactment. These measures, in turn, are represented by the number of topics within the content area in which there is correspondence between intentions and enactment (each content area has 3, 5, or 6 topics). Accordingly, the values (1-3) for each category indicate low, medium or high correspondence in the number of topics as follows: 1) 0 – 1 topic, 2) 2 – 3 topics, or 3) 4 or 5 (6 in the case of geometry) topics. Pearson chi-square test was used to test bivariate relationships within each group of countries. To test the association of factors with instructional time, the Kruskal-Wallis test was performed along with the Mann-Whitney test to examine bivariate associations, given the non-normal distribution of the data for IT. The factors explored in this analysis are teacher collaboration, textbook use, evaluation of teachers’ instructional practice, teacher education, teacher experience, teacher professional development, and teachers’ preparedness to teach.

Teacher collaboration. Figures 5.18 to 5.21 show the distribution of teachers in terms of content topic correspondence given their degree of collaboration. The three-way loglinear analysis testing differences between the two groups in the association of teacher collaboration with OTL produced a model that retained all effects for all four content area topics,\(^\text{72}\) meaning that the highest-order interaction (mean mathematics achievement -teacher collaboration-teachers’ correspondence with intentions) was significant (number topics: \(X^2(4) = 176.89, p <.001\); algebra topics: \(X^2(4) = 21.10, p <.001\); geometry topics: \(X^2(4) = 133.36, p <.001\); data topics: \(X^2(4) = 14.685, p <.05\)).

Separate chi-square tests for low and high performers, showed, for low performers, significant associations between teacher collaboration and teachers’ correspondence with number (\(X^2(4) = 68.92, p <.001\)), algebra (\(X^2(4) = 31.88, p <.001\)) and geometry topics (\(X^2(4) = 49.158,\)

\(^{72}\) The Pearson chi-square statistic for this model was \(X^2(0), p = 1.\)
p <.001). However, Somer’s d statistic, which measured the effect of teacher collaboration on correspondence, is weak in all three cases, although significant (number topics: .15, p<.001; algebra topics: .053, p<.05; geometry topics: .14, p<.001). Standardized residuals in this same group showed that teachers that reported moderate collaboration (sometimes collaborate) were more likely to be in low correspondence in number and geometry topics, and less likely to be in high correspondence in number, algebra and geometry topics. Teachers that reported high collaboration, on the other hand, were less likely to be in low correspondence in number and geometry topics.

In high performing countries, the chi-square test revealed a significant association between collaboration and correspondence for number, geometry and data topics. Somers’ d statistic showed significant, although weak, effects, for number, -.22, p<.001, geometry, -.17, p<.001, and data topics, -.073, p<.001. Interestingly, in contrast to low performers, teacher collaboration seems to have had a negative effect on teachers’ correspondence with intentions in terms of content. These findings are corroborated by the standardized residuals, which show that teachers that reported sometimes collaborating were in higher correspondence in number, geometry and data topics, while teachers that reported being very collaborative were less likely to be in high correspondence in number and geometry topics. Such finding, given the positive effects of teacher collaboration found in the literature (Hargreaves 2009; Lachance & Confrey 2003; Li et al. 2013; Rosenholtz 1989; Stein and colleagues 2007; Suurtam and Gravies 2011; Westheimer 1998) and as has been suggested in relation to the findings of OTL, calls for the reconsideration of the idea alignment as a condition for improved teaching practices and higher student performance.
The three-way analysis to test the association of teacher collaboration and teachers’ emphasis on HDPE and differences in this association between low and high performers using loglinear analysis did not produce significant results. The bivariate relationship between teacher collaboration and emphasis on HDPE was further tested with chi-square tests. The Pearson chi-square statistic showed a significant association between teacher collaboration and teachers’ emphasis on HDPE activities in low, $X^2 (6) = 70.24$, $p < .001$, and high performers, $X^2 (6) = 139.44$, $p < .001$. Somers’ d statistic test, showing the effect of teacher collaboration on the use of HDPE activities, was also significant for both low, -.16, $p < .001$, and high performers, -.21, $p < .001$, although the effect is weak. Notably, the association appears negative for both groups. Such effect was confirmed by the standardized residuals which indicate that teachers that reported to collaborate the least tended to work with HDPE in every or almost every lesson, while those that reported collaborating the most were less likely to work with HDPE with high frequency.

The association of teacher collaboration with instructional time was significant only in the case of low performers $H (2) = 10.951$, $p < .05$. In this group, the Mann-Whitney test showed significant ($p < .05$) differences only between teachers that reported being very collaborative and those being moderately collaborative, the former reporting less instructional time ($U = 203751$, $r = -.086$).

**Textbooks.** Figures 5.22 – 5.24 show the distribution of teachers in terms of content topic correspondence according to the use given to textbooks. The three-way loglinear analysis (mean mathematics achievement-textbook use-teachers’ correspondence with intentions) produced models that retained all effects in the case of number topics ($X^2 (4) = 17.882$, $p < .05$), geometry topics ($X^2 (4) = 10.326$, $p < .05$), and data topics ($X^2 (4) = 49.907$, $p < .001$), meaning differences in
use of textbooks were statistically significant for these three content areas. Chi-square tests performed to break down these effects showed a significant association between the use of textbooks and correspondence with intentions for number, $X^2 (2) = 21.159, p < .05$, geometry, $X^2 (4) = 10.102, p < .05$, and data topics, $X^2 (4) = 15.401 p < .05$, in low performers, and for number, $X^2 (4) = 17.121, p < .05$, and data topics, $X^2 (4) = 42.355 p < .001$, in high performers. However, Somers’ $d$ statistic (not significant for number and geometry topics) or standardized residuals do not show a clear trend in such association.

The three-way association for low/high performing group, teachers' textbook use and the emphasis on HDPE was also tested using loglinear analysis. However, the analysis did not produce statistically significant results. Chi-square test was used to test the bivariate relationship between textbook use and HDPE activities in each group of countries or territory. The association between the two variables was only significant in low performing countries, $X^2 (6) = 24.169, p < .001$. In this group, standardized residuals indicate that when textbooks were used as a supplement, significantly more teachers reported working with HDPE in every or almost every one of their lessons ($z = 3.1$).

According to the Kruskal-Wallis test, the association between the use of textbooks and instructional time is significant for low, $H (2) = 50.914, p < .001$, and high performers, $H (2) = 25.396, p < .001$. Mann-Whitney tests were used to follow up on this finding. In low performers IT did not differ when teachers did not use textbooks compared to when teacher use them as a basis for instruction ($U = 14734, r = -.058$) and as a supplement ($U = 6471, r = -.004$). However, using textbooks as a supplement rather than as a basis for instruction does translate into a significant difference in IT ($U = 213850, r = -.169$); teachers that use textbooks as a supplement also tend to use less IT. However, the effect size is very weak.

73 A Bonferroni correction was applied and so all effects are reported at a .0167 level of significance.
In high performers, significant differences in instructional time were found between the different uses given to textbooks.\textsuperscript{74} However, the size of the effects in all of cases is practically negligible.

**Evaluation.** The analysis of the associations of the activities used to evaluate teachers practice - observations by school staff, observations by inspectors or persons external to the school, student achievement, and teacher peer review – showed significant differences in some cases.

The three-way loglinear analysis to test the association between mathematics performance, observations by principal and staff and teachers’ correspondence with intentions produced a model that retained all effects for number ($X^2 (2) = 114.270, p<.001$), algebra ($X^2 (2) = 35.647, p<.001$), and data topics ($X^2 (2) = 80.038, p<.001$). In low performers Chi-square tests performed to break down these effects indicate significant associations between this type of evaluation and correspondence in number, $X^2 (2) = 23.209, p<.001$, algebra, $X^2 (2) = 6.814, p<.05$, geometry, $X^2 (2) = 56.441, p<.001$, and data topics, $X^2 (2) = 29.950, p<.001$. Although standardized residuals indicate are significant in some cases,\textsuperscript{75} Lambda statistic is either not significant or very weak in all four cases.

In high performers, the bivariate association was also significant for all four content areas. Moreover, Cramer’s V statistic and standardized residuals indicate a significant effect for number, .21, $p<.001$, algebra, .23, $p<.001$, geometry, .101, $p<.001$, and data topics, .23, $p<.001$. However, the association between observations by principals and staff and number topics

\textsuperscript{74} Differences in IT between teachers that use textbooks as a basis for instruction and those that use it as a supplement were statistically significant ($U= 37461$, $r = .066$), as well as between the former and those that did not use textbooks ($U=34699$, $R = .096$). IT differed significantly between teachers using textbooks as a supplement and those that didn’t use them ($U = 9940$, $r = .106$).

\textsuperscript{75} In the case of number ($z=-3.6$), geometry ($z=-4$) and data topics ($z=-4.1$), teachers in schools that did not have this form of evaluation were less likely to be in high correspondence.
correspondence appears to be negative, with teachers that are in schools that do not practice this form of evaluation being more likely to be in correspondence in all number topics ($z=5$). In the case of algebra and geometry, however, the relationship between this type of evaluation and correspondence of enactment with intentions appeared to be positive. See figures 5.25 to 5.28 for an illustration of teachers’ distribution in the two groups.

As for observations by inspectors or other persons external to the school, the three-way loglinear analysis produced a model that retained all effects for number ($X^2 (2) = 8.238, p<.05$) and geometry topics ($X^2 (2) = 12.730, p<.05$), illustrated in figures 5.29 and 5.30. The chi-square tests performed to break down these effects showed a significant and positive association between this type of evaluation and teachers’ correspondence with intentions in low performing countries for algebra, $X^2 (2) = 50.733, p<.001$, geometry, $X^2 (2) = 34.380, p<.001$, and data topics, $X^2 (2) = 65.477, p<.001$, while in high performing countries and territories, the association was also positive and significant for number, $X^2 (2) = 23.243, p<.001$, algebra, $X^2 (2) = 39.485, p<.001$, geometry, $X^2 (2) = 139.315, p<.001$, and data topics, $X^2 (2) = 19.034, p<.001$.

The three-way loglinear analysis for mean achievement, evaluation through student achievement, and teachers’ correspondence with content intentions produced a model that retained all effects for number ($X^2 (2) = 35.643, p<.001$), geometry ($X^2 (2) = 29.342, p<.001$), and data topics ($X^2 (2) = 6.771, p<.05$), indicating differences in this association between low and high performers. Breaking down these effects by group of countries/territories, the chi-square tests performed showed that in low performers, the evaluation of teachers through student achievement is associated with teachers’ correspondence with curricular intentions in the case of number, $X^2 (2) = 12.219, p<.05$, and geometry topics, $X^2 (2) = 32.095, p<.001$. The standardized residuals indicate that in both cases teachers that are in schools that do not perform this type of evaluation are more likely to be in correspondence in all number topics ($z=5$).

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76 The Pearson chi-square statistic for this model was $X^2 (0), p = 1$. 

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evaluation are less likely to be in high correspondence. However, in those schools that do carry on evaluation of teachers by taking into account student achievement the proportion of teachers that are in high correspondence is not significantly higher, as would have been expected given the claim that testing narrows teachers’ focus to tested content, assuming such is aligned with curricular intentions (Hamilton and Berends 2006; Gunzenhauser 2003; Palmer and Snodgrass 2011). In this case, Cramers’ V statistic is very weak for both content areas, .08 and .13, p<.05.

In high performers, the association was significant for all four areas: number, $X^2 (2) = 29.396$, p<.001, algebra, $X^2 (2) = 7.790$, p<.05, geometry, $X^2 (2) = 22.342$, p<.001, and data topics, $X^2 (2) = 40.679$, p<.001. Interestingly, in contrast to low performers, for number, geometry and data topics, standardized residuals indicate that teachers in schools that do not carry on this kind of teacher evaluation are more likely to be in high correspondence.

The three-way loglinear analysis for mean achievement, evaluation through teacher peer review, and correspondence with content intentions produced a model that retained all effects for geometry ($X^2 (2) = 18.461$, p<.001) and data topics ($X^2 (2) = 13.662$, p<.05). Chi-square statistics performed to break down these effects as well as for number and algebra topics revealed that the association between the schools’ evaluation through peer review and correspondence with intentions was significant in all four content areas in low performers (number topics: $X^2 (2) = 88.85$, p<.001; algebra topics: $X^2 (2) = 9.08$, p<.05; geometry topics: $X^2 (2) = 84.013$, p<.001; data topics: $X^2 (2) = 16.218$, p<.001) as well as in high performers (number topics: $X^2 (2) = 121.440$, p<.001; algebra topics: $X^2 (2) = 11.794$, p<.05; geometry topics: $X^2 (2) = 212.711$, p<.001; data topics: $X^2 (2) = 28.626$, p<.001). Cramer’s V statistic shows a stronger association between the two variables for number (.22 and .24) and geometry topics (.21 and .32) in low and high performers, although still weak. In these cases, standardized residuals show that teachers
that worked in schools that carry out this form of evaluation were significantly more likely to be in high correspondence.

The loglinear analysis to test association between these forms of evaluation by schools and teachers’ focus on HDPE across the two groups of countries did not produce a significant model for any of the forms of evaluation.

In relation to evaluation and its impact on IT, the Mann-Whitney test showed significant associations in low performers when teachers work in schools that evaluate their practice through observations by the principal or staff (U=140065, r=-.113, p<.001) (see figure 5.31), observations by inspectors or other persons external to the school (U=308752, r=.079, p<.05), and peer review (U=329518, r=-.076, p<.05). In all of these cases, teachers that were in schools that did not perform these forms of evaluations spent significantly less time teaching mathematics during the year.

In high performers, the association was significant in the case of teachers that worked in schools that evaluated their practice through observations by inspectors or external persons (U=561367, r=.081, p<.001), student achievement (U=275202, r=-.074, p<.001), and teacher peer review (U=625631, r=-.051, p<.05). In all cases teachers in schools that did not perform each kind of evaluation were more likely to employ less IT in their teaching of mathematics.

**Teacher education.** Despite the variation across countries, the bivariate associations between teacher education and OTL variables did show some differences between low and high performers. The log-linear analysis showed that the three-way interaction – mean mathematics achievement, teacher education, and correspondence in content area – produced a model that retained all effects for all four areas (see Table 5.4 for test statistics). However, when looking at
the two-way interactions between teacher education and intention-enactment correspondence, some associations appeared to be more important than others.

In the case of low performers, significant associations were found between teacher education and correspondence in all four content areas. Standardized residuals indicate that in the case of number, algebra and geometry topics, significantly less teachers that majored in mathematics and mathematics education were in low correspondence and/or more teachers were in high correspondence. In other words, having in mathematics and mathematics education made it more likely for teachers to be in closer correspondence with intentions.

In addition, while significantly less teachers with a major in mathematics but no major in mathematics education had low correspondence and more had high correspondence, significantly more teachers majored in mathematics education but not in mathematics showed low correspondence and less showed high correspondence in number, algebra and geometry topics. Apparently, having stronger mathematics knowledge meant more teachers corresponded to intentions, while the opposite was the case for teachers having pedagogical training. Teachers having other majors and no post-secondary education seemed to negatively affect correspondence in the case of number, algebra and geometry topics in low performers. Figures 5.32 through 5.35 illustrate the distribution of teachers in terms of correspondence by type of education.

In the case of high performing countries, although the associations are significant with all content areas, Lambda statistic shows a weaker association. Standardized residuals show significant differences in the case of algebra and geometry topics with teachers majored in mathematics education but not in mathematics, showing a tendency to have more high correspondence and less low correspondence. A significantly lower proportion of teachers with a
major in mathematics and mathematics education are in low correspondence with intentions for algebra topics, while significantly more of those with other majors or no post-secondary education are in low correspondence for algebra and geometry topics.

The difference in the association between teacher education and HDPE was found statistically significant between the low and high performing groups\(^{77}\), \(X^2 (12) = 27.998, P<.05\). The two-way interactions examined with separate cross-tabulation of teacher education and HDPE for low and high performing groups also showed significant associations (LP: \(X^2 (12) = 44.513, p <.001\); HP: \(X^2 (12) = 32.402, p <.05\)). However, standardized residuals did not indicate a clear trend in the type of teacher education and the use of HDPE in low or high performers, and Lambda statistic was not significant in either group.

Overall, the type of knowledge that translates into higher correspondence between intentions and enactment in eighth grade mathematics or teaching more HDPE is unclear for low and high performers, as previous studies have also indicated (Blomeke 2012). It is clear, however, given the significant differences between teachers with a major in one or both types of knowledge – mathematical and pedagogical – and those with other majors and no post-secondary education, that preparation in mathematics as well as mathematics pedagogy are highly relevant for student learning, as other studies have also suggested (Clotfelter et al. 2007; Sowder 2007).

**Teacher experience.** The three-way loglinear analysis for mean mathematics achievement, teachers’ years of experience, and teachers’ correspondence to curricular intentions produced models that retained all effects in all four content areas,\(^{78}\) meaning that the highest-order interaction (mean mathematics achievement-teacher’s years of experience-teachers’

\(^{77}\)The three-way interaction mean mathematics achievement, teacher education and HDPE retained all effects \((X^2 (12)= 27.998, P<.05)\). The Pearson chi-square statistic for the model was \(X^2 (0), p=1\).

\(^{78}\)The Pearson chi-square statistic for this model was \(X^2 (0), p = 1\).
correspondence with intentions) was statistically significant (number topics: $X^2 (8)= 91.75$, $p < .001$; algebra topics: $X^2 (6)= 38.139$, $p < .001$; geometry topics: $X^2 (6)= 78.53$, $p < .001$; data topics: $X^2 (6)= 16.32$, $p < .05$). To break down this effect, separate chi-square tests on teachers’ years of experience and teachers’ correspondence for each content area variables were performed for low and high performers. Differences are illustrated in figures 5.36 to 5.39.

In low performers, a significant association was found between years of experience and teachers’ correspondence with curricular intentions for number, algebra and geometry topics ($p<.05$), while in high performers the association was significant for all four content areas. Standardized residuals indicate that in low performing countries teachers with less experience were more likely to correspond with intentions in only few number topics (teachers with 5 or less, or with 5 to 10 years of experience) and in geometry topics (teachers with 5 years of experience), while teachers with more than 20 years were less likely to correspond in few number topics. In high performing countries, standardized residuals show that teachers with the least experience (less than 5 years) were more likely to have high levels of correspondence in number and geometry topics, while the opposite is true for teachers with more than 20 years of experience. This finding is particularly interesting as it suggests that as teachers acquire more knowledge and abilities through experience, they also possibly exercise higher levels of autonomy and therefore diverge more from curricular intentions.

The tests for differences in IT in relation to teachers’ years of experience are significant for low, $H (3) = 32.548$, $p<.001$, and high performers, $H (3) = 19.491$, $p<.001$. The Mann-Whitney tests to identify relationships with each category revealed that in low performing countries teachers with 20 years of experience or more employed significantly less time than teachers with less experience (less than five years: $U=88574$, $r = -.11$; 5-10 years: $U=90945$, $r = -$
In high performing countries, only teachers with 20 years or more of experience use significantly less IT than teachers with 5-10 years of experience (U=115685, r = -.16). In high performing countries, only teachers with 20 years or more of experience use significantly less IT than teachers with 5-10 years of experience (U=171889, r = -.12). Figure 5.40 illustrates these differences.

Results suggest that experience matters in teachers’ ability to enact the curriculum. More experience possibly provides teachers with knowledge and abilities to teach mathematics, make a more efficient use of time, and make better decisions about what to teach and how to teach addressing student needs and classroom context.

**Teacher professional development.** The three-way loglinear analysis for mean mathematics achievement, PD focused on content knowledge, and correspondence of intentions and enactment, illustrated in figures 5.41 to 5.44, produced a model that retained all effects in all four content areas, meaning differences were significant between the two groups. The chi-square tests for the bivariate associations between PD for content and teachers’ correspondence with intentions produced a significant association between PD focused on content and teachers’ correspondence for number, geometry and data topics in low performers and all four content areas in high performers. In the low performing group, content focused PD appears to have had a positive effect; standardized residuals indicate that teachers with this type of PD are more likely to be in high correspondence for number and geometry topics. In high performers, this is the case with algebra, geometry and data topics. However, Lambda statistic is in all cases 0 or not significant.

The three-way loglinear analysis for mean mathematics achievement, pedagogy focused PD, and correspondence with content produced a model that that retained all effects only in the case of number ($X^2 (2) =11.095, p <.05$) and algebra topics ($X^2 (2) =20.337, p <.001$), illustrated

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79 The Pearson chi-square statistic for this model was $X^2 (0), p = 1$. 

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in figures 5.45 and 5.46. To break down this effect, separate chi-square tests on teacher participation in pedagogy focused PD and correspondence variables were performed for low and high performers. A significant association was found between these two variables for number, $X^2(2) = 13.558$, $p<.05$, and geometry topics, $X^2(2) = 14.780$, $p<.05$, in low performing countries, although Lambda statistic indicates a weak and no effect of PD on content correspondence. In the high performing group, pedagogy focused PD appeared to be associated to correspondence in all content areas (number: $X^2(2) = 17.8$, $p<.001$; algebra: $X^2(2) = 29.681$, $p<.001$; geometry: $X^2(2) = 32.296$, $p<.001$; data: $X^2(2) = 26.387$, $p<.001$), where teachers seemed to be in higher correspondence with intentions when they had participated in this type of PD. However, Lambda statistic indicates no effect, as in the case of low performers.

The three-way loglinear analysis for mean mathematics achievement, PD focused on curriculum development, and correspondence for content taught produced a model that that retained all effects in the case of number ($X^2(2) = 113.975$, $p=.001$), algebra topics ($X^2(2) = 15.535$, $p=.001$), and geometry ($X^2(2) = 40.524$, $p=.001$) topics, the association for these content areas and PD for curriculum development in low and high performers is shown in figures 5.47 to 5.49. The chi-square tests to break down the effects revealed significant associations in low performing countries between PD focused on curriculum development and correspondence for number topics, $X^2(2) = 95.506$, $p=.001$, geometry, $X^2(2) = 60.814$, $p<.001$, and data topics, $X^2(2) = 42.903$, $p<.001$, in which teachers that reported participating were more likely to be in high correspondence.

Although teachers’ participation in PD focused on critical thinking was not significantly different between low and high performers, the three-way loglinear analysis (mean mathematics

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80 The Pearson chi-square statistic for this model was $X^2(0)$, $p = 1$.

81 The Pearson chi-square statistic for this model was $X^2(0)$, $p = 1$. 

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achievement - critical thinking PD - correspondence) produced a model that retained all effects in the case of number $X^2 (2)=46.594$, $p=.001$, algebra, $X^2 (2)=10.580$, $p=.05$, and geometry topics, $X^2 (2)=13.133$, $p=.05$. However, although the Pearson chi-square tests performed to break down these effects showed statistically associations for some of the content areas, Lambda statistic showed no effects.

The three-way loglinear analysis for mean mathematics achievement, PD for assessment, and correspondence produced a model that retained all effects only in the case of number ($X^2 (2) = 81.414$, $p<.001$) and geometry topics ($X^2 (2) = 41.916$, $p=.001$). Breaking down this effect, chi-square tests indicate that the association between PD for assessment and correspondence is significant in low performing countries for number, $X^2 (2) = 96.741$, $p<.001$ and geometry topics, $X^2 (2) = 73.093$, $p<.001$. The standardized residuals indicate that teachers that participated in this type of PD are more likely to be in high correspondence with intentions in both areas. In the case of high performers, although some associations were significant, there were no clear trends, while Lambda statistic was weak or non-existent in nearly all cases.

The three-way loglinear analysis for mean achievement, PD focused on student needs, and content correspondence produced a model that retained all effects for all four content areas (number: $X^2 (2) = 51.310$, $p=.001$; algebra: $X^2 (2) = 6.215$, $p<.05$; geometry: $X^2 (2) = 18.255$, $p<.001$; data: $X^2 (2) = 11.883$, $p<.05$). In testing the bivariate relationships between this type of PD and correspondence in each content area in low performing countries, significant results were produced for all areas (N: $X^2 (2) = 45.884$, $p<.001$, A: $X^2 (2) = 10.662$, $p<.05$, G: $X^2 (2) = 21.34$, $p<.001$, D: $X^2 (2) = 13.729$, $p<.05$), although the Lambda statistic was very weak or 0.

Standardized residuals, however, do show a positive association between participation and high

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82 The Pearson chi-square statistic for this model was $X^2 (0)$, $p = 1$.

83 The Pearson chi-square statistic for this model was $X^2 (0)$, $p = 1$. 
correspondence in number, geometry and data topics. In high performing countries or territories, test statistics did not show significant associations or effects.

The three-way loglinear analysis testing the association of mean mathematics achievement, PD, and HDPE produced different results for each type of PD activity. For PD focused on curriculum development and critical thinking, the model produced retained all effects, meaning that the interaction between these three variables is significantly different across the two groups (see figure 5.50). In the case of curriculum development and its association to teachers’ use of HDPE, the chi-square test showed it was significant, \( X^2 (3) = 56.342, p<.001 \), for low performing countries as well as for high performers, \( X^2 (3) = 66.154, p<.001 \). In both cases standardized residuals indicate that teachers that participated in this type of PD were more likely to focus on HDPE activities in every or almost every lesson.

As for PD for critical thinking, the association with HDPE activity was also significant for both groups, with standardized residuals also indicating that teachers that participated were more likely to emphasize HDPE with high frequency, as expected, considering that critical thinking promotes higher order thinking processes (see figure 5.51). Somers’ d statistic was for low and high performers significant for both types of PD, indicating a weak effect of participation and teaching with HDPE.

In relation to the rest of the PD activities, in spite of no differences identified in their association to teachers’ HDPE between low and high performers, chi-square tests do show that the bivariate association is significant in each group, although the strength of the association appears weaker in the case of pedagogy PD. In the case of PD for content and assessment, standardized residuals indicate that teachers that participated in each were more likely to focus more frequently on HDPE, the effect being considerably stronger in high performers. PD for

\[84\] The Pearson chi-square statistic for this model was \( X^2 (0), p = 1 \).
student needs also stands out as having had positive effect, particularly on high performers, where significantly more teachers focused on HDPE when they had participated in this type of PD.

The tests for the association between participation in PD and IT in low and high performing countries also showed significant differences in some types of PD activities. Figures 5.52 through 5.56 show the time distribution by country group given teachers’ participation in the various kinds of PD activities. According to the Mann-Whitney test, IT was significantly higher for teachers that participated in PD related to content (LP: U=331912, r = -.09; HP: U=538626, r= -.15), curriculum development (LP: U=342064, r = -.06; HP: U=535552, r =-.18), critical thinking (LP: U= 326481, r = -.08; HP: U= 537263, r = -.14), assessment (LP: U = 338560, r = -.08; HP: U= 551679, r = -.15), and student needs (LP; U= 306237, r = -.07; HP: U= 612317, r = -.07) in both low and high performers. Notably, the effect of participation in PD activities appears to have been higher in the high performing group in all cases except for PD for student needs. The association between PD focused on pedagogy and IT was only significant (U=560725, r=-.104) for high performing countries.

Overall, the findings in relation to the associations between teachers’ participation in PD activities are weak and inconsistent. Some of these, however, suggest that participation in PD matters more in low performers for correspondence between intentions and enactment and that participation in PD in high performers promotes the more frequent emphasis on HDPE.

5.4. Summary and conclusions

The analysis of the policies that constitute curriculum governance systems suggests that there is an important degree of convergence in the policy instruments used across education
systems. First and foremost, most countries have established a national curriculum, of which, as seen in the previous chapter specifically for mathematics, some content is shared. Other policy instruments, ones that have more recently emerged, are also common across many of the countries explored, including more demanding teacher preparation requirements to enter the teaching service, high stakes testing, and textbook approval processes.

Overall, the review of policies across countries indicates no clear differences in curricular governance systems between low and high performers. Policies, some of which are considered world-best policies, exist in both high and low performing countries or territories, which contradicts the claim that certain policies or policy structures are ideal in ensuring higher achievement. Instead, this finding is consistent with the view of institutional isomorphism shaping policies and policy structures that are increasingly common across education systems ((McEneaney and Meyer, 2000; Meyer, Heinz-Dieter and Rowan 2006). It is also in line with the policy-borrowing trends driven by international standardized testing and the worldwide comparison practices that these have promoted (Kamens and Benavot 2011; Steiner-Khamsi 2004). As countries seek for solutions to the problem of poor education outcomes, with more frequency, they adopt the policies of countries identified as high performers by international assessments, assuming, without question, that they are the reason for the high achievement.

However, as discussed in the literature, the differences in outcomes of common policy structures policies seem to interact with elements of the system, the context, and the actors, producing distinct patterns of implementation that are more than likely to differ from intentions, therefore, also producing varying results. The implementation of curricular policy that precedes these particular outcomes can be understood within a policy adaptation process, which several authors have characterized in their studies in various ways (Fullan and Promfet 1977; Honig
The processes involved include the interpretation of (complex) policy messages, as well as implementers’ agency, understood as the capacity to act based on their own decisions, both occurring within a frame of actors’ particular culture, ideology, history, resources, and expertise (Campbell 2012; Biesta and Tedder 2006, 2007; Nudzor 2009; Priestley et al. 2012; Spillane 2000; Spillane et al. 2002; Trowler 1998). Implementation is also defined by social, governance and institutional structures and their interaction, for they support, limit or alter the processes assumed by policy makers. It is often the lack of consideration of these elements that leads to policies’ ineffectiveness or failure, as policy adoption often assumes conditions – cultural, social and institutional – and resources that often do not exist.

In addition, given the low level of convergence between the intended and the enacted curriculum in both groups and the similarities and governance systems, findings also bring into question the idea that a system with more or specific policy instruments will translate into higher levels of convergence between policy and instruction. These conclusions are in line with the evidence that suggests that control is not strictly associated with higher achievement (Wiseman and Brown 2003). Rather than control of instructional processes, systems should recognize teachers’ autonomy and the need for teachers to be capable of exerting such adequately and assume responsibility for their practice. Such view would imply setting curricular governance systems with a different aim.

Despite the commonalities across groups, some differences were identified. For example, teacher preparation and certification requirements for entering the teaching profession were more demanding in high performing countries. In addition, more recent policies seem to be present to a higher degree in high performing countries, as is the case of induction programs for incoming
teachers, which, according to studies, have a positive effect on teachers’ practice and professional development.

The results of the bivariate analyses exploring the associations between different factors and teachers’ enactment of the curriculum, or OTL, as well as comparing these associations between low and high performers showed considerable variation across factors. Although clear and strong patterns did not emerge from this analysis, these differences between low and high performers provide further evidence of the effects of context factors on OTL. These findings are summarized and discussed in relation to the literature in the following paragraphs.

First, significant differences between low and high performers were found in the association between teacher education and all four mathematics content areas and between teacher education and teacher focus on HDPE, suggesting that teacher education, which the literature shows matters to student outcomes, matters to what and how teachers teach (Blomeke 2012; Clotfelter et al. 2007; Sowder 2007). In low performing countries, mathematics knowledge and knowledge to teach mathematics are both important for teachers’ covering intended content topics. In teaching more complex content topics, having content knowledge appears to be associated with teaching that is in higher correspondence with intentions. Clearly, teachers will not teach content that they do not master.

In high performing countries, the type of teacher education appears to have had a lower effect on whether teachers covered intended topics, and while no training in either of these fields or no post-secondary education was negatively associated with convergence, pedagogical training seems to have been more important than mathematics knowledge to teachers’ corresponding with intentions.
Possible explanations for these findings are inferred from other studies. First, recognizing that the content and quality of teacher education programs vary across countries (Blomeke 2012; Schmidt et al. 2011; Tatto and Senk 2011;), in many developing countries these programs have been found to be of poor quality, while teachers possibly also had poor prior education; in this case, having a stronger mathematics background makes a difference. In high performers, on the other hand, where university programs provide a better education in general, pedagogical training possibly gives teachers a stronger sense of responsibility towards achieving the goals of the education system. These hypotheses, however, need to be further explored.

And while teacher education appears to have no impact on the frequency with which teachers employ HDPE activities, it does seem to influence IT. In low performing countries teachers with training in mathematics education used less IT than teachers with any other type of education. In contrast, in high performing countries, teachers prepared in mathematics and mathematics education seemed to employ more time in teaching mathematics.

With small effects, differences were also significant for the associations of teacher experience and teacher collaboration with the four mathematics content areas, although that was not the case for HDPE or IT. Teachers’ years of experience appears to have had the opposite effect in low and high performers. While in low performers, experience seems to have been important for teachers’ coverage of intended content topics in some areas, in high performers, more experience was more likely to be a factor for lower correspondence; on the other hand, teachers with less experience tended to be in high correspondence for the same content areas. It is possible, given these findings, that as teachers gain more experience, have had access to better training, and face less restraints within the school and classroom context, they are able to comfortably and more professionally exercise their autonomy and make better decisions about
content coverage than their less experienced peers; this may imply diverging from curricular intentions, as it occurs in high performers. Teachers in low performers would have likely received little support throughout their teaching career that helped them develop professionally. Finally, for low performers more experience also translates into less instructional time, a finding that may be linked to teachers’ becoming more knowledgeable in using time more efficiently.

Collaboration also appeared to have opposite effects in low and high performers in relation to its association with the teaching of content topics. While for low performers teachers that did not collaborate were less likely to correspond to curricular intentions in number, algebra and geometry topics, in high performers teachers that were very collaborative were less likely to correspond to intentions in number and geometry topics. These findings, although not conclusive, suggest that the effect of teacher collaboration depends on the conditions created by the context and the policies and characteristics of the education system in which it occurs. For teachers with poor preparation, teacher collaboration may be strongly grounded on curricular prescriptions, making teachers be in higher correspondence. For teachers that are better prepared to teach mathematics, on the other hand, collaboration may not be so strongly focused on the curriculum, content and other prescriptions.

A study by the Schleifer and colleagues (2017) highlights several benefits of teacher collaboration; for example, teachers learn from other teachers’ instructional practice or share information about students; both practices foster that teachers adjust their practices in response to students’ knowledge or lack thereof. Talbert and McLaughlin (2002), in a study of the effects of teacher communities on teachers in schools in the United States, found that in schools with traditional forms of teacher organizing, teaching innovations were restrained by narrowed curricula, testing and academic tracking; in contrast, teachers in schools with strong teacher
collaboration were more inclined and able to develop and try new teaching ideas to support student learning. Consistent with this study’s findings, collaboration seems to have the potential to foster instructional practices that respond to student needs in creative ways, rather than feel restricted by policy mandates.

Exploring these assumptions and the role of teacher collaboration in specific contexts will take further research. However, the findings help highlight the importance of the characteristics of teacher collaboration to have the effects desired; collaboration alone does not translate into better instruction or student learning outcomes (Hargreaves 1992; Hargreaves 2009; Hargreaves 2013).

The association of teacher collaboration and work with HDPE was similar in low and high performers. Unexpectedly, however, results suggest that more collaboration translates into a less frequent teaching for HDPE. As for IT, higher collaboration seemed to translate in less IT for a significant number of teachers. While collaboration may help teachers use time more effectively, the finding in relation to HDPE requires further consideration, given the finding that teachers in low performers engage more frequently with HDPE in their teaching.

A significant difference between the groups of countries was also found in relation to the association between teachers’ participation in all six types of PD and intended content coverage. However, differences were significant for only some content areas. Notably, only the interaction relative to mean achievement, PD for student needs (reported to a higher extent by teachers in high performing countries), and content coverage maintained the highest order effect for all four content areas. In the case of the association of PD and teachers’ work with HDPE, analysis showed significant associations in the case of two types of PD: curriculum development, in which case only high performers showed an association to more frequent use of HDPE, and PD
for critical thinking, for which the relationship was found to be stronger in high performers. Surprisingly, PD for pedagogy did not result in significant differences in the use of HDPE in either group. Notably, in all cases where differences were significant in the bivariate relationship, the effect size appeared to be stronger in high performers, which could be indicative of the quality of PD opportunities.

Interestingly, the use of textbooks and its association with coverage of intended content topics was significantly different between low and high performers in all areas, except for algebra, but differences were not identified for the use of HDPE or IT. Bivariate analyses for textbook use and teachers’ enactment of the curriculum did show some common relationships in both groups of countries, but effect size was very weak or even negligible. Despite the widespread use of textbooks for instruction, the results indicate variation in their possible role. Undoubtedly and as the literature also indicates, the support or effect textbooks can have, depends largely on their content, the degree to which such is aligned with curriculum standards and the degree to which they promote more challenging thought processes. Furthermore, reliance on textbooks may also depend on teachers’ content and pedagogical knowledge, widening differences in the use and impact of the textbook as a tool for instruction.

Similarly, the association between the four different forms of evaluation of teacher practice, which were reported by the schools, and content coverage also appeared to differ between low and high performers, although in each case for different content areas. In low performers, findings show that all forms of evaluation, a mechanism for teacher control, translated into teachers being more likely to cover intended topics for some content areas, as was expected, as was expected. But in the case of high performers evaluation produced inconsistent results across content areas. These findings suggest a stronger effect of policy instruments related
to supervision and evaluation on teachers’ practice in countries with low performance, which are likely to have weaker teacher preparation and professional development programs. However, the degree to which this influence promotes better teaching is questionable.

In contrast, there seemed to be no significant differences in the association between evaluation and teachers’ instructional focus on HDPE between low and high performers. Neither student assessment, used to a higher extent in low performers, or teacher peer review appeared to make be associated with teachers’ coverage of HDPE.

Overall, the results of these analyses suggest that different factors surrounding teachers’ instruction influence their practice. Although the individual effects are weak, the interaction of these elements is likely to produce larger effects, as economic, political and social contextual factors also have a bearing in how policies are enacted. Second, as teachers’ decisions assess and respond to specific context needs, strict correspondence between intentions and enactment may not necessarily translate into higher student learning. Having said this, it can be argued that more effective systems set in place the conditions for teachers to be prepared to respond to students’ needs, improving the possibility of correspondence with curricular intentions.

Finally, the expected variation in the association of these factors with elements of OTL within countries and across the two groups of countries underscores the differentiated influence of policies on teachers’ decisions and, in turn, on student learning. It, then, can be argued that policies drawn from a set of existing ‘best world practices’ and instated as positive and effective policies are more than likely not interpreted, understood and enacted by those responsible of putting them into actions in the terms that are envisioned outside of any context by policymakers.
## 5.5. Figures and Tables

Table 5.1. National instructional policy in high and low performing countries or territories

<table>
<thead>
<tr>
<th>Country</th>
<th>Main preparation route for most teachers in the 8th grade</th>
<th>Supervised practicum</th>
<th>Qualifying examination or certification</th>
<th>Complete probationary teaching period</th>
<th>Complete mentoring or induction program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese Taipei</td>
<td>University degree</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Finland</td>
<td>University master's degree with major in subject</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Hong Kong SAR</td>
<td>Teacher college program or university degree</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Japan</td>
<td>Lower secondary school teaching certificate and appointment examination</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Korea</td>
<td>Training for 4 years under mixed system of exclusive and open training systems (teachers colleges and universities).</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>State universities or pedagogical university or institutes. Pre-service teacher education by the National Institute of Education. Four-year programs with education major and the 1- or 2-year Postgraduate Diploma in Education</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Singapore</td>
<td>Education University degree, usually specializing in 2 subjects. Requirements set by states. For most teachers it is a university degree program in education</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Slovenia</td>
<td>University degree, usually specializing in 2 subjects. Requirements set by states. For most teachers it is a university degree program in education</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>United States</td>
<td>University degree program and some attend professional institute programs (no bachelor's degree).</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Chile</td>
<td>Teacher college program and teacher certificate</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Indonesia</td>
<td>University (bachelor's degree): education and mathematics education.</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Iran, Islamic Rep. Of</td>
<td>Teacher training course for which teachers are eligible after a Diploma of General University Studies (D.E.U.G) or BA/BS degree.</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Lebanon</td>
<td>University degree in the subject area they teach in school plus attending &quot;psychopedagogical module&quot; that includes curriculum, assessment and didactics.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Morocco</td>
<td>4-year teacher education college program (some with university degree in two subjects)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Norway</td>
<td>University degree in the subject area they teach in school plus attending &quot;psychopedagogical module&quot; that includes curriculum, assessment and didactics.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Romania</td>
<td>At least a bachelor's degree with 1 year of specific coursework in teaching.</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Thailand, Republic of</td>
<td>4-years university degree programs.</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table 5.2. National instructional policy in low performing countries

<table>
<thead>
<tr>
<th>Country</th>
<th>High stakes testing for mathematics</th>
<th>National curriculum that covers mathematics instruction at 8th grade</th>
<th>Year the (tested) mathematics curriculum was introduced</th>
<th>Mathematics curriculum currently being revised</th>
<th>Curriculum prescribes</th>
<th>Is there process for approving textbooks for mathematics instruction?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese Taipei</td>
<td>Yes</td>
<td>Yes</td>
<td>2003</td>
<td>Yes</td>
<td>Goals and objectives; instructional processes or methods; materials; assessment methods/activities</td>
<td>Yes</td>
</tr>
<tr>
<td>Finland</td>
<td>Yes</td>
<td>Yes</td>
<td>2004</td>
<td>No</td>
<td>Goals and objectives; assessment methods/activities</td>
<td>No</td>
</tr>
<tr>
<td>Hong Kong SAR</td>
<td>Yes</td>
<td>Yes</td>
<td>2002</td>
<td>No</td>
<td>Goals and objectives; instructional processes or methods; materials; assessment methods/activities</td>
<td>Yes</td>
</tr>
<tr>
<td>Japan</td>
<td>Yes</td>
<td>Yes</td>
<td>2009</td>
<td>No</td>
<td>Goals and objectives; instructional processes or methods; materials; assessment methods/activities</td>
<td>Yes</td>
</tr>
<tr>
<td>Korea</td>
<td>Yes</td>
<td>Yes</td>
<td>1997</td>
<td>Yes</td>
<td>Goals and objectives; instructional processes or methods; materials; assessment methods/activities</td>
<td>Yes</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>Yes</td>
<td>Yes</td>
<td>2004</td>
<td>Yes</td>
<td>Goals and objectives; instructional processes or methods; materials; assessment methods/activities</td>
<td>Yes</td>
</tr>
<tr>
<td>Singapore</td>
<td>Yes</td>
<td>Yes</td>
<td>2008</td>
<td>Yes</td>
<td>Goals and objectives; instructional processes or methods; materials; assessment methods/activities</td>
<td>Yes</td>
</tr>
<tr>
<td>Slovenia</td>
<td>Yes</td>
<td>Yes</td>
<td>1998</td>
<td>Yes</td>
<td>Goals and objectives; instructional processes or methods; assessment methods/activities</td>
<td>Yes</td>
</tr>
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<td>United States</td>
<td>Varies by state</td>
<td>Varies by state</td>
<td>Varies by state</td>
<td>Varies by state</td>
<td>Goals and objectives; The curriculum also prescribes minimal compulsory contents.</td>
<td>Yes</td>
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<tr>
<td>Chile</td>
<td>Yes</td>
<td>Yes</td>
<td>2010</td>
<td>Yes</td>
<td>Goals and objectives; instructional processes or methods; materials; assessment methods/activities</td>
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<tr>
<td>Indonesia Iran, Islamic Rep. Of</td>
<td>Yes</td>
<td>Yes</td>
<td>2006</td>
<td>No</td>
<td>Goals and objectives; instructional processes or methods; materials; assessment methods/activities</td>
<td>Yes</td>
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<th>Country</th>
<th>Assessment</th>
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<th>Materials</th>
<th>Assessment</th>
<th>Year</th>
<th>Notes</th>
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<td>Lebanon</td>
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<td>Yes (not for 8th grade)</td>
<td>Yes</td>
<td>1998</td>
<td>Yes</td>
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<tr>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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<td>Norway</td>
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<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>2006</td>
<td>No</td>
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<tr>
<td>Romania</td>
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<td>Yes</td>
<td>Yes</td>
<td>2005</td>
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</tr>
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<td>Thailand</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>-2010</td>
<td>Yes</td>
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<td>Turkey, Republic of</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2008</td>
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<td>Ukraine</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2005</td>
<td>Yes</td>
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Table 5.3. Policy instruments broadly applied by teachers or schools by country

<table>
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<th>Country</th>
<th>Curriculum governance indicators</th>
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<tr>
<td>Chile</td>
<td>▷ ◊ ● □ △ † † ‖</td>
</tr>
<tr>
<td>Indonesia</td>
<td>+ ◊ ● □ △ † † ‖</td>
</tr>
<tr>
<td>Iran</td>
<td>† □ △ †</td>
</tr>
<tr>
<td>Lebanon</td>
<td>□ △ † ‖</td>
</tr>
<tr>
<td>Morocco</td>
<td>▷ □ △ †</td>
</tr>
<tr>
<td>Norway</td>
<td>□ † ‖</td>
</tr>
<tr>
<td>Romania</td>
<td>* + ● □ △ † ‖</td>
</tr>
<tr>
<td>Thailand</td>
<td>+ † ◊ □ △ † ‖</td>
</tr>
<tr>
<td>Turkey</td>
<td>□ △ †</td>
</tr>
<tr>
<td>Ukraine</td>
<td>+ † ◊ ● △ □ △ † ‖</td>
</tr>
<tr>
<td>Chinese Taipei</td>
<td>+ □ △ †</td>
</tr>
<tr>
<td>Finland</td>
<td>□ †</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>+ † ◊ □ △ † ‖</td>
</tr>
<tr>
<td>Japan</td>
<td>† □ △ †</td>
</tr>
<tr>
<td>Korea</td>
<td>□ △ † ‖</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>+ † □ △ † ‖</td>
</tr>
<tr>
<td>Singapore</td>
<td>+ † □ △ † ‖</td>
</tr>
<tr>
<td>Slovenia</td>
<td>□ △ †</td>
</tr>
<tr>
<td>United States</td>
<td>+ † ◊ △ †</td>
</tr>
</tbody>
</table>

More than 2/3 (67%) of teachers or schools report having:

- Major in mathematics and mathematics education *
- Participation in professional development in mathematics content +
- Participation in professional development in pedagogy †
- Participation in professional development in curriculum development ◊
- Participation in professional development in critical thinking ○
- Participation in professional development in assessment ●
- Used textbooks as the basis for instruction □
- Evaluation through observations by the principal or senior staff △
- Evaluation through observations by inspectors or external persons Δ
- Evaluation through student achievement †
- Evaluation through peer review ‖

Figure 5.1. Percentage of teachers reporting collaboration per group of countries or territories

https://timssandpirls.bc.edu/timss2011/international-database.html
Figure 5.2. Percentage of teacher collaboration by country
Figure 5.3. Percentage of teachers reporting textbook use during instruction in low and high performers

Figure 5.4. Percentage of teachers according to the role they give to textbooks in each country

Figure 5.5. Percentage of schools of students tested that report using different forms of evaluation of mathematics teachers’ practice

Figures 5.6. Percentage of schools that perform evaluation in each country

Figures 5.7. Percentage of schools that perform evaluation in each country

Figure 5.8. Teacher preparation in low and high performing countries or territories

Figure 5.9. Teachers education by country

Figure 5.10. Teacher experience in low and high performing countries and territories

Figure 5.11. Teacher experience by country

Figure 5.12. Percentage of teacher who feel very well prepared to teach the content topic by group

<table>
<thead>
<tr>
<th>Country/content topics</th>
<th>Computing, estimating, or computing with fractions</th>
<th>Concepts and computing with decimals</th>
<th>Representing, comparing, ordering, and proportion</th>
<th>Problem solving, percents &amp; proportion</th>
<th>Simplifying, numeric, algebraic, &amp; geometric patterns</th>
<th>Simplifying, evaluating algebraic expressions and inequalities</th>
<th>Simple linear equations and inequalities</th>
<th>Simultaneous equations (two variables)</th>
<th>Representation of functions, geometric properties &amp; shapes</th>
<th>Congruent figures and similar triangles</th>
<th>Relationships, p: 3D shapes &amp; their 2D projection</th>
<th>Using measurement formulas, p, c, a &amp; v</th>
<th>Points on the Cartesian plane, translation, reflection, and rotation</th>
<th>Reading &amp; displaying data sets (e.g., predict, determine chances)</th>
<th>Judging, predicting, and determining chances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lebanon</td>
<td>92.9%</td>
<td>95.5%</td>
<td>92.2%</td>
<td>94.2%</td>
<td>95.3%</td>
<td>97.3%</td>
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<td>93.8%</td>
<td>94.4%</td>
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<td>93.8%</td>
<td>97.3%</td>
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<tr>
<td>Morocco</td>
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<td>96.1%</td>
<td>99.3%</td>
<td>99.4%</td>
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<td>93.8%</td>
<td>94.4%</td>
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<td>93.8%</td>
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<td>83.8%</td>
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<td>96.1%</td>
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Figure 5.13. Teachers’ reported preparedness to teach by country: percentage of teachers that feel very well prepared to teach the content topic. Source: TIMSS 2011 Assessment. International Association for the Evaluation of Educational Achievement (IEA). Publisher: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College. Online database, accessed January 8, 2013, https://timssandpirls.bc.edu/timss2011/international-database.html
Figure 5.14. Percentage of teachers that reports having participated in professional development during the last two years in low and high performing countries and territories

<table>
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<tr>
<th>Country</th>
<th>Math content</th>
<th>Math pedagogy</th>
<th>Math curriculum</th>
<th>Information technology</th>
<th>Critical thinking</th>
<th>Math assessment</th>
<th>Student needs</th>
</tr>
</thead>
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<tr>
<td>Chile</td>
<td>64.0%</td>
<td>46.2%</td>
<td>39.0%</td>
<td>47.8%</td>
<td>33.7%</td>
<td>32.1%</td>
<td>54.3%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>71.2%</td>
<td>54.2%</td>
<td>71.8%</td>
<td>59.4%</td>
<td>57.1%</td>
<td>70.6%</td>
<td>46.7%</td>
</tr>
<tr>
<td>Iran, Islamic Republic of</td>
<td>52.1%</td>
<td>68.4%</td>
<td>31.9%</td>
<td>40.4%</td>
<td>40.9%</td>
<td>31.6%</td>
<td>41.3%</td>
</tr>
<tr>
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<td>56.0%</td>
<td>56.1%</td>
<td>47.5%</td>
<td>55.8%</td>
<td>57.7%</td>
<td>52.1%</td>
<td>50.6%</td>
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<tr>
<td>Morocco</td>
<td>43.4%</td>
<td>58.0%</td>
<td>47.1%</td>
<td>60.2%</td>
<td>29.3%</td>
<td>33.7%</td>
<td>21.3%</td>
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<td>Norway</td>
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<td>27.9%</td>
<td>16.2%</td>
<td>16.1%</td>
<td>14.5%</td>
<td>30.2%</td>
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<tr>
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<td>46.9%</td>
<td>49.0%</td>
<td>78.5%</td>
<td>55.7%</td>
</tr>
<tr>
<td>Thailand</td>
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<td>79.5%</td>
<td>59.9%</td>
<td>57.6%</td>
<td>62.8%</td>
<td>29.3%</td>
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<tr>
<td>Turkey</td>
<td>28.8%</td>
<td>38.8%</td>
<td>29.7%</td>
<td>27.1%</td>
<td>30.5%</td>
<td>25.0%</td>
<td>63.3%</td>
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<tr>
<td>Ukraine</td>
<td>78.2%</td>
<td>44.8%</td>
<td>83.3%</td>
<td>79.6%</td>
<td>62.6%</td>
<td>71.8%</td>
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</tr>
<tr>
<td>Chinese Taipei</td>
<td>71.0%</td>
<td>59.9%</td>
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<td>47.7%</td>
<td>31.3%</td>
<td>41.4%</td>
<td>58.0%</td>
</tr>
<tr>
<td>Finland</td>
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<td>19.1%</td>
<td>7.2%</td>
<td>10.3%</td>
<td>3.3%</td>
<td>9.1%</td>
<td>56.6%</td>
</tr>
<tr>
<td>Hong Kong, SAR</td>
<td>47.6%</td>
<td>57.6%</td>
<td>48.3%</td>
<td>49.0%</td>
<td>49.0%</td>
<td>60.0%</td>
<td>48.3%</td>
</tr>
<tr>
<td>Japan</td>
<td>39.0%</td>
<td>49.7%</td>
<td>40.3%</td>
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<td>33.2%</td>
<td>37.8%</td>
<td>46.9%</td>
</tr>
<tr>
<td>Korea, Republic of</td>
<td>49.2%</td>
<td>56.6%</td>
<td>47.3%</td>
<td>37.5%</td>
<td>32.5%</td>
<td>43.5%</td>
<td>40.1%</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>52.2%</td>
<td>58.8%</td>
<td>67.6%</td>
<td>23.3%</td>
<td>44.2%</td>
<td>35.5%</td>
<td>48.5%</td>
</tr>
<tr>
<td>Singapore</td>
<td>58.8%</td>
<td>79.9%</td>
<td>54.4%</td>
<td>48.3%</td>
<td>48.9%</td>
<td>58.8%</td>
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</tr>
<tr>
<td>Slovenia</td>
<td>54.1%</td>
<td>59.6%</td>
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<td>37.6%</td>
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<tr>
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<td>57.7%</td>
<td>66.4%</td>
<td>61.0%</td>
<td>61.9%</td>
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</tr>
</tbody>
</table>

Figure 5.15. Percentage of teachers that report participating in professional development activities by country or territory

Figure 5.16. Teachers’ perceptions about the expectations for student achievement by other teachers in their school

Figure 5.17. Teachers’ perceptions about the expectations for student achievement by other teachers in their school by country

Figures 5.18. Percentage of teachers corresponding with intended number topics by teacher collaboration


Figures 5.19. Percentage of teachers corresponding with intended algebra topics by teacher collaboration

Figures 5.20. Percentage of teachers corresponding with intended geometry topics by teacher collaboration


Figures 5.21. Percentage of teachers corresponding with intended data topics by teacher collaboration

Figure 5.22. Percentage of teachers corresponding with intended number topics by use of textbooks

Figure 5.23. Percentage of teachers corresponding with intended geometry topics by use of textbooks
Figures 5.24. Percentage of teachers corresponding with intended data topics by use of textbooks

Figures 5.25. Percentage of teachers corresponding with intended number topics relative to teacher evaluation
Figures 5.26. Percentage of teachers corresponding with intended algebra topics relative to teacher evaluation

Figures 5.27. Percentage of teachers corresponding with intended geometry topics relative to teacher evaluation
Figure 5.28. Percentage of teachers corresponding with intended data topics relative to teacher evaluation

Figure 5.29. Percentage of teachers corresponding with intended number topics relative to teacher evaluation
Figure 5.30. Percentage of teachers corresponding with intended geometry topics relative to teacher evaluation

Figure 5.31. Instructional time given participation in teacher evaluation through observations by principals or persons in the school
Figures 5.32. Percentage of teachers corresponding with intended number topics by teacher education

Source: TIMSS 2011 Assessment. International Association for the Evaluation of Educational Achievement (IEA). Publisher: TIMSS & PIRLS
Figures 5.33. Percentage of teachers corresponding with intended algebra topics by teacher education

Figures 5.34. Percentage of teachers corresponding with intended geometry topics by teacher education

Figures 5.35. Percentage of teachers corresponding with intended data topics by teacher education

Figure 5.36. Percentage of teachers corresponding with intended number topics by teacher experience

Figure 5.37. Percentage of teachers corresponding with intended algebra topics by teacher experience
Figure 5.38. Percentage of teachers corresponding with intended geometry topics by teacher experience

Figure 5.39. Percentage of teachers corresponding with intended data topics by teacher experience
Figure 5.40. Instructional time distribution according to teachers’ years of experience

Figure 5.41. Percentage of teachers corresponding with intended number topics by teacher education
Figure 5.42. Percentage of teachers corresponding with intended algebra topics by teacher education


Figure 5.43. Percentage of teachers corresponding with intended geometry topics by teacher education

Figure 5.44. Percentage of teachers corresponding with intended data topics by teacher education
Source: TIMSS 2011 Assessment. International Association for the Evaluation of Educational
Achievement (IEA). Publisher: TIMSS & PIRLS International Study Center, Lynch School of Education,
Boston College. Online database, accessed January 8, 2013,
https://timssandpirls.bc.edu/timss2011/international-database.html

Figure 5.45. Percentage of teachers corresponding with intended number topics by participation
in professional development in pedagogy
Source: TIMSS 2011 Assessment. International Association for the Evaluation of Educational
Achievement (IEA). Publisher: TIMSS & PIRLS International Study Center, Lynch School of Education,
Boston College. Online database, accessed January 8, 2013,
https://timssandpirls.bc.edu/timss2011/international-database.html
Figure 5.46. Percentage of teachers corresponding with intended algebra topics by participation in professional development in pedagogy

Figure 5.47. Percentage of teachers corresponding with intended number topics by participation in PD
Figure 5.48. Percentage of teachers corresponding with intended algebra topics by participation in PD

Figure 5.49. Percentage of teachers corresponding with intended geometry topics by participation in PD
Figure 5.50. Teachers’ coverage of high demanding performance expectations (HDPE)
Source: TIMSS 2011 Assessment. International Association for the Evaluation of Educational
Achievement (IEA). Publisher: TIMSS & PIRLS International Study Center, Lynch School of Education,
Boston College. Online database, accessed January 8, 2013,
https://timssandpirls.bc.edu/timss2011/international-database.html

Figure 5.51. Teachers’ coverage of high demanding performance expectations (HDPE)
Source: TIMSS 2011 Assessment. International Association for the Evaluation of Educational
Achievement (IEA). Publisher: TIMSS & PIRLS International Study Center, Lynch School of Education,
Boston College. Online database, accessed January 8, 2013,
https://timssandpirls.bc.edu/timss2011/international-database.html
Figure 5.52. Instructional time distribution according to teachers’ participation in professional development.

Figure 5.53. Instructional time distribution according to teachers’ participation in professional development.
Figure 5.54. Instructional time distribution according to teachers’ participation in professional development.


Figure 5.55. Instructional time distribution according to teachers’ participation in professional development.

Figure 5.56. Instructional time distribution according to teachers’ participation in professional development

Table 5.4. Associations between group mathematics performance, factors, and OTL.

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<th>Three-way model: Country group/FACTOR/OTL element</th>
<th>Loglinear analysis: Likelihood ratio</th>
<th>Statistic highest order interaction</th>
<th>Chi-square statistic for two-way associations: Factor* low performing group</th>
<th>Chi-square statistic for two-way associations: Factor* high performing group</th>
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<tr>
<td>Country group / teacher education / number topic correspondence</td>
<td>$X^2 (0), p = 1$</td>
<td>$X^2 (8) = 123.874**$</td>
<td>$X^2 (8) = 303.57**$</td>
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<td>$X^2 (8) = 31.65**$</td>
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correspondence
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Country group / Evaluation – observations by staff / number topic correspondence
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Country group / observations by staff / algebra topic correspondence
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Country group / observations by staff / geometry topic correspondence
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Country group / observations by staff / data topic correspondence
\[ X^2(0), p = 1 \]
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\[ X^2(2) = 29.950** \]
\[ X^2(2) = 111.286** \]
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Country group / E – student achievement / algebra topic correspondence
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Country group / E – student achievement / HDPE
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*p<.05

**p<.001
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<th>Association tested</th>
<th>Kruskal-Wallis test statistic Low performers</th>
<th>Kruskal-Wallis test statistic High performers</th>
<th>Mann-Whitney test statistic Low performers</th>
<th>Mann-Whitney test statistic High performers</th>
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<tbody>
<tr>
<td>Teacher education / IT</td>
<td>H (4) = 38.90**</td>
<td>H (4) = 31.292**</td>
<td>U=42729, r = -.176***</td>
<td>U=130534, r = -.045</td>
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<td>Mathematics and mathematics education vs. mathematics education but not in math</td>
<td>U=161900, r = -.0096</td>
<td>U=287388, r = -.10946***</td>
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<td>Mathematics education and mathematics vs. all other majors</td>
<td>U=51804, r = -.0012</td>
<td>U=116773, r = -.0296</td>
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<td>Mathematics and mathematics education vs. no post secondary education</td>
<td>U=43007, r = -.084</td>
<td>U=1671, r = -.1097***</td>
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<td>Mathematics education but not in mathematics vs. mathematics but not in mathematics education</td>
<td>U=45097, r = -.17743***</td>
<td>U=152305, r = -.0436</td>
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<td>Mathematics education but not in mathematics vs. all other majors</td>
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<td>Mathematics not in mathematics education vs. all other majors</td>
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<td>U=744, r = -.1592***</td>
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<td>Teacher experience / IT</td>
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<td>H (3) = 19.491**</td>
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<td>U=88574, r = -.112***</td>
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<tr>
<td>Less than 5 yrs./20 yrs. or more</td>
<td>U = 56936, r = -.054</td>
<td>U = 122949, r = -.051</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-10 yrs./10-20 yrs.</td>
<td>U=90945, r = -.094***</td>
<td>U=171889, r = -.115***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-10 yrs./20 or more</td>
<td>U=115685, r =</td>
<td>U = 204532, r</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-20 yrs./20 or more</td>
<td></td>
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</tr>
</tbody>
</table>
Professional development content / IT
\( U = 331912, r = -.161*** \)
\( U = 538626, r = -.074** \)

Professional development pedagogy / IT
\( U = 362148, r = -.09** \)
\( U = 538626, r = -.153 \)

Professional development curriculum development / IT
\( U = 342064, r = -.062 \)
\( U = 538626, r = -.182** \)

Professional development critical thinking / IT
\( U = 326481, r = -.075* \)
\( U = 537263, r = -.144** \)

Professional development assessment / IT
\( U = 338560, r = -.077** \)
\( U = 551679, r = -.153** \)

Professional development student needs / IT
\( U = 306237, r = -.073* \)
\( U = 612317, r = -.076** \)

Teacher collaboration / IT
\( H(2) = 10.951*, r = 1.012 \)

Sometimes collaborative/collaborative
\( U = 133248, r = -.038 \)
\( U = 273861, r = -.008 \)

Sometimes collaborative/very collaborative
\( U = 67762, r = -.05 \)
\( U = 106216, r = -.033 \)
\( U = 203751, r = -.086* \)
\( U = 373426, r = -.017 \)

Collaborative/very collaborative
\( U = 213850, r = -.169** \)
\( U = 374461, r = -.066*** \)

Textbooks / IT
\( H(2) = 50.914**, r = 25.396** \)

Basis for instruction vs. supplement
\( U = 213850, r = -.169** \)
\( U = 374461, r = -.066*** \)

Basis for instruction vs. not used
\( U = 14734, r = -.058 \)
\( U = 34699, r = -.096** \)

Supplement vs. not used
\( U = 6471, r = .004 \)
\( U = 9940, r = -.106* \)
\( U = 308752, r = -.079* \)
\( U = 561367, r = -.081** \)
\( U = 140065, r = -.113** \)
\( U = 238716, r = -.033 \)

Evaluation - inspectors’ visits / IT
\( U = 329518, r = -.076* \)
\( U = 625631, r = -.051* \)

Evaluation - observations by staff / IT
\( U = 94268, r = -.018 \)
\( U = 275202, r = -.074** \)

* \( p < .05 \)
** \( p < .001 \)
*** \( p < .005 \)

***Test statistic is significant if \( p < .005 \)
Chapter 6. DISCUSSION AND CONCLUSIONS

This dissertation has sought to identify differences between the opportunities to learn mathematics given to students across low and high performing countries, according to their mean achievement in TIMSS, and the possible association of these opportunities to specific policies in the curriculum governance structure and to teacher individual characteristics. The questions that guided the analyses are:

- Concerning curriculum policy enacted in classrooms:
  
  d. What is the mathematics curriculum enacted by eighth grade teachers in high and low achieving countries?
  
  e. In what ways does the enacted mathematics curriculum of high and low performing countries differ?
  
  f. What is the relationship between the enacted curriculum and the intended curriculum in high and low achieving countries?

- Concerning the mathematics enacted curriculum and various system and teacher factors:
  
  g. Do curricular governance systems differ between low and high performers?
  
  h. Are specific policy instruments or teacher factors associated with eighth grade teachers’ decisions in the enactment of the mathematics curriculum in high and low achieving countries?
  
  i. Does the association between policy instruments and teacher factors with the eighth grade enacted mathematics curriculum differ between high and low achieving countries?
Overall, the results of the analyses carried out to respond to these questions showed that broad variation exists in the enactment of the curriculum across the countries and territories examined, but also within countries, depicting a wide gap between intentions and enactment in both low and high performers. Intended curricula, on the other hand, showed much less divergence across countries and across groups, evidence of the ongoing policy convergence across education systems. Regarding the enacted curriculum and its relationship to specific factors, the analysis also showed variation across the two groups, showing differences in the strength, direction and significance of the associations. This chapter discusses the findings for each of the research questions in the light of the related literature.

6.1. The mathematics curriculum enacted by teachers in low and high performers

6.1.1. Common OTL

The analysis of OTL mathematics in low and high achieving countries or territories in general showed students across countries, throughout their first eight years of schooling, are provided OTL topics in the four content areas considered in this study: numbers, geometry, algebra, and data. Such finding is consistent with previous analysis of the mathematics curriculum and how it has evolved in past decades (Schmidt et al. 2001; Baker et al 2010). Within the four content areas several of the topics examined are commonly taught across these countries or territories, from first through eighth grade, although the time at which they are taught varied across countries.

Algebra and data topics, which have been given increasing attention in the intended curriculum and moved to earlier grades in the past decades in high performers (Baker et al. 2010; Schmidt et al 2001), were found to be part of the enacted curriculum in both low and high
performers. Number topics, which generally introduce mathematics learning in primary education, continued to be part of the enacted curriculum up to the eighth grade in both groups, in spite of their absence from the intended curriculum for such grade. The first of these findings indicates that the implementation of curricular policies has indeed shifted in the direction of policy prescriptions, as neoinstitutionalists would argue, explaining this gradual correspondence as a result of larger forces – political, social and cultural – influencing institutions and driving policy change globally (McEneaney and Meyer, 2000, Meyer and Rowan 2006). The latter finding, in contrast, reflects teachers’ continued divergence from policy prescriptions, suggesting a strong influence of local context on teachers’ decisions. Thus, teachers respond to the following, not in order of importance: directives in the education governance system; broader national and international forces, understanding that beyond national policies, broader ideas and beliefs about the world shape how teachers’ view and assume their role; and finally, their specific education context, including own and student characteristics, as well as school context.

Specifically, during 8th grade, in general, findings show that more advanced mathematics content topics were covered, mostly algebra and geometry topics, which corresponds to curricular intentions. However, coverage was partial in all countries; according to teacher responses, many of the content topics in these areas were only covered by a small percentage of teachers in countries from both groups. The teaching of data topics, in contrast, received less attention by teachers across countries, while number topics were covered by a considerable percentage of teachers in some countries, although not intended.

The kinds of performance expectations and instructional strategies used to teach topics, at first glance, depict shared approaches to the teaching of mathematics: students are asked to listen to teachers explain how to solve problems, memorize rules, procedures and facts, apply these
facts, concepts and procedures to solve routine problems, explain their answers, work on problems with the teachers’ guidance, or relate what they are learning to daily life, for example. Such important degree of common practices suggests a mathematics instruction that is similar across classrooms around the world, and, accordingly common understandings of mathematics teaching and learning throughout differing contexts, despite their epistemological diversity. Previous analyses of the mathematics curriculum have highlighted the well-defined content domains and integrated knowledge structure of mathematics as a field of knowledge (Benavot 2012), explaining common content and structures in the mathematics curriculum across countries. Further analysis of these practices, however, is needed of these practices, the teacher-student interactions they generate, and the effect they have on student learning.

The analysis of the specific topics, the frequency of different types of performance expectations and instructional strategies, and the IT devoted to the teaching of mathematics revealed important differences in the enactment of the curriculum between the two groups, but also across countries. These differences reflect how ideas and concepts, as well as the policies that they are part of, become grounded in ways that are specific to the context, as they likely respond to economic, social, and cultural factors (Vavrus and Bartlett 2012). This broad variation found within groups in relation to all four elements of OTL is discussed in what follows.

6.1.2. Differences in OTL

Teachers’ reports about the specific topics, how they were covered and for how much time, specifically during the 8th grade, reveal important differences in the enactment of the curriculum between the two groups of countries or territories. They also showed wide variation within each group in relation to the OTL provided to students.
In the aggregate, teachers in high performers seemed to enact a more challenging mathematics curriculum in the 8th grade, although not all elements of OTL showed this pattern. Overall, a combination, in general terms, of more challenging content topics, less IT, a continued emphasis on the less demanding performance expectations and instructional strategies, and a lower emphasis on the more demanding performance expectations and instructional strategies – when compared to that made by low performers’ teachers – characterized mathematics instructional practices in these countries or territories. Findings for each of the elements of OTL are discussed in more detail.

To begin, teachers in high performers reported the introduction of more advanced topics occurring earlier in the schooling progression, as was identified by Schmidt and colleagues in 1997 and more recently by Benavot (2012) for developing countries; in addition, these topics are covered more extensively. Many algebra and geometry as well as data topics are introduced in primary school; by the 8th grade they have been covered extensively, with few exceptions. During the eighth grade, algebra and geometry topics seemed to be more prominent in the enacted curriculum in high performers than in low performers.

Unexpectedly, teachers’ coverage of more challenging mathematics content did not seem to occur in parallel with more challenging performance expectations or instructional strategies, at least when compared to the coverage of such in low performers. Teachers in high performers reported emphasizing high demanding performance expectations with significantly less frequency than low performers’ teachers. Reasoning mathematically, which entails students explaining answers, working on problems for which there is no obvious solution, or deciding on their own solutions, for example, are processes that, according to reports, were not so frequently promoted in their mathematics classes. In fact, less than 50% of teachers reported working on
these higher-order thinking strategies in half of their lessons, at the most, a percentage that contrasts sharply with low performers’ close to 70% percent of teachers using these strategies in almost every lesson or about half the lessons.

These findings seem to contradict earlier studies that describe Singapore, Japan and other high performers as countries that place a strong emphasis on highly challenging thinking processes, such as problem solving, communicating mathematically, critical thinking, and abstract reasoning; these and other studies suggest this emphasis is key to high performance (Dindyal 2006; OECD 2011a, 2011b; Schmidt et al. 2001; Schmidt et al. 1997; Valverde and Naslund 2010). However, given higher mean mathematics scores, the unexpected lower emphasis on these processes in comparison to low performers elicits possible hypotheses, discussed in paragraphs below.

Furthermore, in contrast to the less emphatic use of HDPE, teachers in several high performers reported promoting low demanding performance expectations extensively, with some exceptions. Although somewhat unexpected, this finding supports the argument that mastering LDPE is necessary to be able to teach more complex PE and for students to go into more challenging thought processes. The TIMSS study, for example, identifies knowing as the more basic performance expectation and recognizes that without this knowledge base “that allows the easy recall of the language and basic facts and conventions of number, symbolic representation, and spatial relations, students would find purposeful mathematical thinking impossible” (TIMSS 2011, 41). Accordingly, the results suggest that teachers’ strong emphasis on memorization of basic facts and procedures and other LDPE are important for students to understand and master the more demanding PE and, ultimately, achieve better learning. Such findings are relevant to
current policy trends that intend to dismiss memorization and procedural knowledge, assuming it diminishes learning.

For Lesh and Zawojewski (2007), however, this strong emphasis on less challenging cognitive skills, gradually deemphasized in curricular intentions to give room to the more challenging ones, responds to current trends in standardized assessment, which, in general, measure basic skills to a greater extent. However, the differences between low and high performers in terms of the effect of standardized assessments on teachers practice are not explained. Certainly, the relative importance of different types of PE and their significance to learning and mastering complex thought processes is a topic for future study. These findings also call for further research on the extent to which teachers in contexts that place a strong emphasis on assessment favor LDPE over HDPE in their instructional practices.

In addition, in high performers, teachers’ coverage of more advanced content topics with a lower emphasis on the more challenging performance expectations and instructional strategies and more attention to LDPE during the eighth grade was coupled with, overall, less IT devoted to the subject, in comparison with low performers. Algebra topics were given the most IT by the majority of teachers in most of the high performers. There was more variation of the average IT devoted to geometry, while data topics, on average, received the lowest percentage of IT across these countries. Worth noting is the finding that all Asian countries had lower percentages of IT devoted to number topics during the eighth grade. In general, reported IT was consistent with teachers’ reports regarding content topic coverage.

The importance of IT, perhaps the element of OTL most explored in previous OTL studies, to learning gains and achievement has been identified in empirical research. Its effect on learning has been associated to the structure of the curriculum and context (Schmidt et al.
However, it has also been found that it is not just time in class, or allocated time, or even IT – the time when teachers are teaching and not doing other activities that are not related to learning – that translates into students’ learning, but rather the time when students are actually engaged in a learning activity, also known as time-on-task or active learning time (Huyvaert 1998; Fisher and Berliner 1985).

The closer correspondence with prescribed IT as well as, on average, less IT employed by teachers in high performers than those in low performers suggest that teachers in these higher achieving countries were making a more effective use of time; that is, they had more time on task or active learning with their students. Furthermore, given reported IT and content topics covered, teachers in high performers possibly spend more engaged time on the more challenging topics. A better use of IT, in which students are engaged in learning activities, requires, as a starting point, that teachers are well prepared to teach and that schools have created the adequate conditions for learning. Research on school conditions in developing countries as well as the more recent studies on teachers’ education evidence that these conditions are less likely to be met in developing countries (Ingvarson et al. 2013), most of which show low levels of achievement in international assessments.

In contrast, the OTL reported by teachers in low performers showed a less demanding enacted curriculum. Although topics in all four content areas were covered and to a similar extent as that in high performers, it is the less demanding of these that become part of the enacted curriculum in the majority of classrooms. On average, teachers reported spending more IT on these topics during the eighth grade than teachers in high performers; also, the variation of such time within these countries is higher, which reflects lower correspondence with intended IT

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85 Schmidt et al. (2001) clarify that the association between instructional time and learning gains interacts with textbook space and content topics.
for teachers in low performing countries. However, the most surprising finding of the study was seen in PE and IS; unexpectedly, teachers in low performers reported using the more demanding performance expectations and instructional strategies with considerably high frequency, and to a significantly higher extent than teachers in high performers did.

Considering the schooling progression prior to eighth grade, while number topics had been covered broadly by this grade, algebra, geometry, and data topics had been covered to a lower extent in low performers. It is the more basic algebra and geometry topics — *simplifying and evaluating algebraic expressions* and *simple linear equations and inequalities* — that had broader coverage, while a significant percentage of teachers had not approached some of the more advanced topics, even when some of them were included in the intended curriculum. This continued to be the case during the eighth grade.

Moreover, although number topics continued to be taught into the eighth grade in both low and high performers, this was the case to a higher extent in low performers, where teachers dedicated an important amount of time to teaching them after primary education and specifically during eighth grade. The decision to devote considerable time to number topics, even when not intended, is likely teachers’ response to students’ lack of mastery of these topics and to the need to achieve such in order to be able to learn new and more complex content. These decisions that diverge from policy mandates provide evidence to support the view of teachers as agents that enact a curriculum following their perceptions of students’ needs, while also constrained by

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86 An important percentage (up to 75%) of teachers in some low performing countries covers some of these topics. In some cases, specifically Chile, Morocco, and Norway, this is, at least in part, due to the fact that number topics are still intended in the 8th grade mathematics curriculum. However, in others, specifically Chile, Lebanon, Norway and Thailand, some of these topics are taught during 8th grade in spite of their exclusion from curricular intentions.

Furthermore, while in high performers teachers appear to be moving towards more challenging topics in the higher grades, teachers in low performers continue to devote much of the 8th grade IT to number topics. Ten years earlier, Schmidt et al. (2001) found a similar general pattern: more teachers covering arithmetic topics during the eighth grade translated into a smaller the percentage of them covering algebra or geometry topics. Overall, in terms of content topics, students in low performing countries were given less challenging OTL mathematics than those in high performers.

In contrast to the teaching of less challenging content topics in low performers, teachers reported a strong emphasis on HDPE and HCIS during the eighth grade. Most teachers in low performers informed they promoted that their students decide on their own procedures for solving complex problems, work on problems for which there is no immediately obvious solution, and other challenging strategies in about half of their lessons or in every or almost every lesson.

The inconsistency in these findings is not only in relation to what teachers in high performers have reported. Analyses of mathematics’ teachers practice in countries with higher student achievement show that teaching to develop more challenging cognitive abilities is a complex process that does not occur without well directed efforts. Cuban (2013), indeed, argues that there is a continued emphasis on lecture-driven lessons across systems over the broadly prescribed intellectually challenging and collaborative teaching and learning processes, an indication of slow change in policy implementation. Furthermore, Spillane (2000), in a study of

---87 Arithmetic topics clustered in eighth grade’s OTL negatively correlated to the coverage of geometry and algebra topics.
United States classrooms, found that teachers favor procedural knowledge over conceptual and more in depth understanding, while the few analyses of mathematics curriculum implementation in specific contexts in Panama and Costa Rica show that teachers have weak mathematics pedagogical knowledge (Sorto et al. 2008 in Valverde and Naslund-Hadley 2010); these claims contravene the findings in this study.

As briefly discussed in chapter 4, the findings in relation to the emphasis made on HDPE in low performers, in the first place, question the validity of the reported data and summon the following conjectures. Differences between low and high performers are likely due to measurement error in the data reported by teachers in the low performing group, attributed, in turn, to specific situations. For one, responses may reflect a policy discourse identified in recent reforms that emphasizes the need to develop students’ higher-order cognitive skills, including analyzing, reasoning, and conjecturing\(^8\) (Benavot 2012, Schmidt et al. 1997; Dindyal 2006; Maclean 2001 in Lesh and Zawojewski 2007; Elliot and Kenny 1996; Spillane 2000). But as the literature on policy implementation and enactment suggests, this discourse does not necessarily translate into teaching practices that effectively result in students carrying out or developing the ability to conduct such cognitive processes. Teachers adopt the language of the new policy and they may also, at best, adopt changes in their practice that they believe to be in line with the reform; however, their interpretations and sense-making processes of the new concepts and ideas, limited by their prior knowledge and experience and by inadequate guidance and poor professional development, may differ from the actual meanings of the policy concepts (Spillane

\(^8\) This trend is evident in Benavot’s (2012) study of reading and mathematics primary education curricula across developing countries. Although the prevalence of cognitively challenging performance expectations in curricular documents varies across countries for fifth and sixth grade, a tendency was found in more than half of the countries to increase performance standards by grade level; thus, we would expect more complex and challenging curricular intentions at the eighth grade. Overall, the study indicates that in many of the developing countries analyzed, the intended curriculum contains a large proportion of cognitively challenging material.
This “misinterpretation” on the part of teachers would translate into a practice that, although may be intended to follow new policy prescriptions, does not in reality promote the challenging cognitive processes that are said to be promoted.

The complexity in interpretation processes, which depends on various factors, including teacher knowledge, is documented in the literature as one of the main reasons for inconsistency in what is taught by teachers in a given context (Spillane 2000). A specific reason to believe that this could be the case is that performance expectations are not unambiguous, as is mostly the case for content topics, and therefore the activities that lead to their development, possibly explained or instructed to teachers inadequately, are likely to be less (uniformly) understood by teachers. Thus, for example, teachers may ask students to explain answers, but they do not act to elicit more higher-order thinking processes, by asking further and more challenging questions, or by providing feedback to their answers.

A second reason for measurement error, although less likely, could be in the survey questions themselves and their (mis)representation of activities that call for low or high cognitively challenging thought processes. This possibility highlights the need to evaluate and improve the use of survey methods to capture teaching, on one side, and self-reported data, on the other. It is particularly relevant for processes that are not unambiguous, such as pedagogical practices intended to promote specific thought processes. More specifically, it points to the need to further assess the adequacy of survey questions applied by the IEA, as well as other international studies, across contexts with important social, cultural, and, mainly, epistemological differences, as well as the processes employed to adapt them.

The lack of validity in the responses of the survey could also be attributed to the desirability of the responses perceived by teachers. That teachers respond according to what they
believe is desired, possibly considering the national curriculum and their obligation to align with such, also calls for a careful evaluation of survey questions and responses. But more importantly, this thesis would reflect teachers’ lack of understanding and mastery of teaching more challenging mathematics content, for such mastery would imply being able to discern how unlikely it is to perform to such standard, and, consequently, report more closely to actual practice.

Another possibility, and question for further exploration, is that teachers’ reported focus on HDPE reflects teachers’ stronger emphasis due to students having more difficulty mastering these and teachers’ persistent efforts to develop better cognitive abilities in students. The causes of this could be several and related to students’ learning needs or to the classroom context. For example, students may be behind in their learning, so teachers make persistent efforts to teach the content or develop abilities; classroom discipline problems may limit learning and increase required time and efforts.

In these cases, as well as in those discussed earlier in this study, teachers make decisions about what to teach influenced by and responding to their specific context. They use their partial autonomy, anticipate the alternatives and act. In doing so, teachers reflect their capacity to make these decisions, that is, to exercise agency.

As mentioned earlier, IT devoted to mathematics by teachers in low performers was on average higher than that of high performers, while in general variances for each country were wider, as expected. Many of the low performers had higher percentages of IT for coverage of number topics, while lower percentages for algebra topics, in general, which, consistent with the reported content coverage portray lower OTL for students in low performing countries.
Overall, the OTL given to students in low performing countries in general differ from those provided to students in high performing countries or territories. Despite possible measurement error in the reported data for performance expectations and instructional strategies, OTL for the former are lower, a finding that points to the significance that teachers’ enacting of the curriculum has to achievement.

Having noted these differences between the two groups, not all countries within these fit into these general patterns, and, in fact, deviate considerably from them. High performing Chinese Taipei stands out with a curriculum that includes number, algebra and geometry topics up to the 8th grade, and are all extensively covered, focusing on only few topics in each grade level. This is consistent with Valverde and Schmidt’s (2000) descriptions of high performers – those that cover fewer topics in each grade level in greater depth, rather than a higher number of topics covered superficially.

Finland was a country with a distinct characterization of the OTL provided to students; however, it has stood apart from the group of high performers not having met the criteria for such, but rather having been included as a case to analyze given its consistently high average achievement in PISA since 2000. Finland showed a unique enacted curriculum, as well as particularities in its curricular intentions, but it was consistent with some of the findings for high performers: algebra prevails in the 8th grade over other topics in terms of IT. As reported in chapter 4, although 4 of the 5 algebra topics and all of the geometry topics are part of the country’s curricular intentions, Finnish teachers reported considerably low coverage of algebra, geometry and data topics. In spite of this low coverage, teachers reported spending the highest proportion of the time devoted to mathematics during the eighth grade to teaching algebra topics. They also reported teaching topics that in other countries or territories were reported covered early in the schooling progression mostly until the eighth grade; such is the case of problem solving involving percents and proportions.
does not meet what could be the global criteria for “best practice” can also lead to high performance.

6.2. Correspondence between the enacted and the intended curriculum

Given the differences in the enacted curriculum between the two groups of countries, the next question explored was the degree of correspondence between intentions and enactment of the mathematics curriculum in the eighth grade or equivalent. Knowing that curricular policy influences teachers’ instructional decisions, the expectation was that curricular intentions of low performers would be less challenging. Assuming differences in intentions, it was also expected to find less correspondence between the intended curriculum and enactment in low performers.

As expected, the analysis showed low correspondence between intentions and enactment in low performers; topics intended were not covered extensively by teachers – in some cases minimally – while topics not intended for the eighth grade were covered by a considerable percentage of teachers.

The correspondence of PE between intentions and enactment was of particular interest, given the strong emphasis on them reported by teachers in low performers. Although intended PE reported by countries lacked specificity, it was found that more of the low performers – in comparison to high performers – intended lower emphasis on highly challenging performance expectations, a characteristic that has been ascribed to the curriculum of developing countries (Valverde 2004).

This moderate emphasis of intentions on reasoning and relating mathematics to daily life found in several low performers is inconsistent with teachers’ reported strong coverage of this type of expectations, making the questions posited in the previous section more relevant. If
teaching HDPE is not emphasized in learning intentions, why do teachers make such strong emphasis on these in their practice?

Clearly, considering only curricular intentions and teachers actions presents an incomplete view. As mentioned above, focusing on developing higher order thinking abilities has been in the center of the education discourse for the past decade. The OECD’s PISA, for example, in which many countries, including the majority in this study, participate, speaks about acquiring the type of knowledge that can be applied to real life situations,\(^90\) referring to learning that goes beyond basic skills and that develops the more demanding analytic, reasoning and communication abilities. How these understandings about teaching and learning mathematics influence teachers’ own interpretations and assumptions about their practice is, given the results of this study, a question for future analysis. For example, these accepted conceptions, although not present or emphasized in curricular intentions, possibly permeate through other mechanisms, such as textbooks. Ultimately, these ideas about the importance of higher order cognitive abilities appear to be spreading and integrating themselves into curricular policy as well as actors’ own language about teaching mathematics, an argument that neoinstitutionalism, discussed above, would help explain (McEneaney and Meyer 2000; Meyer and Rowan 2006).

Correspondence of intended IT and the actual IT devoted to mathematics teaching (percentage of the total IT) also revealed important differences between low and high performers. Even though there was variation in the percentage of time teachers reported in both groups of countries, the measure varied considerably less in most of the high performers. In contrast, an important percentage of teachers in low performers deviated and deviated further from intentions. Overall, these findings show an enacted mathematics curriculum that diverged

\(^{90}\) See http://www.oecd.org/pisa/aboutpisa/
from intentions to a higher degree in low performers, indicating a strong influence of other factors on teachers’ decisions and, consequently, teachers’ need to adjust their practice.

The literature has pointed out many of these factors, some of which have been mostly identified in low income countries. As this scholarship suggests, among the many reasons for the lack of correspondence between intentions and teachers’ enactment of the curriculum is students’ lack of mastery of previous mathematics content and the consequential need for teachers to recall or reteach content. In the 8th grade, the cumulus of mathematics knowledge students should have and need in order to learn new and more complex topics is greater, making it more likely that students enter the grade with weaknesses, especially in low performers.

Other reasons for teachers’ divergence from curricular intentions are larger class sizes, student discipline problems, and the lack of teaching and learning materials. The lack of alignment between intentions and textbooks or standardized assessments is also a factor that influences teachers’ instruction. However, these elements imply teachers making decisions, which consider, as well, their own history and characteristics, mainly their subject and pedagogical knowledge and the opportunities they have had for professional development (Honig, 2006; Priestley et al. 2012; Spillane 2000, 2002).

However, in spite of the differences found between the groups, surprisingly, high performers also showed considerably low levels of correspondence between intentions and enactment, particularly in content topic coverage. On average, about half the teachers in high performers – similar percentage as low performers - reported not teaching the prescribed algebra and geometry topics, those mostly prescribed for the eighth grade. In addition, according to their reports, an important percentage of teachers in some of the high performers decided to

\footnote{Geometry has lower coverage, although there is more extensive coverage of geometry topics in earlier grades in comparison to algebra topics.}
cover number topics *during the eighth grade*, even when these were not part of the intended curriculum. That is, while teachers in high performers possibly had less challenges and more support to enact the intended curriculum, they still made decisions that diverged from curricular prescriptions.

These results reflect not only divergence from intentions, but also low levels of consistency within countries or territories of instructional practice among teachers. This finding is particularly relevant, for it occurs in spite of having a national curriculum, accompanied by curricular governance systems that intend to exert a high degree of control over instructional practice, as was discussed in chapter 5 (Gvirtz and Beech 2004).

Furthermore, having found that teachers in high performers were not in strict correspondence with curricular intentions, results challenge the claim that alignment is central to ensure high achievement. As discussed in the review of the literature, the failure of teachers to ‘align’ their practice to the intended curriculum is deemed problematic, particularly from the fidelity perspective (Fullan and Promfet 1977; Roach et al. 2008; Snyder et al. 1992). Under this hierarchical and controlling view of teaching, teachers are assumed passive deliverers of curricular prescriptions (Craig 2012), and, as such, are not recognized as professionals that require, and indeed have, certain degree of autonomy; the divergence of the enacted curriculum from curricular intentions in both low and high performers reflects this autonomy. When knowledge, experience and reflective processes guide teachers’ instructional decisions, made within this frame of autonomy, it is more likely that decisions respond to student needs; teachers are capable of identifying these needs and redefine their teaching accordingly. This redefinition may imply shifting away from curricular intentions, but it will also likely conduce to better student learning.
Recognizing autonomy, on the other hand, does not diminish the importance of national learning goals. Views about an implementation that is in line with these goals propose coordinated and reflexive decisions and actions among the different actors that constitute the governance structures, as well as policy enactors (Biesta and Tedder 2006; Branyon 2012; Campbell 2012; Lasky 2005; Priestly et al. 2012; Valverde 2004). Curricular convergence, accordingly, suggests curricular governance structures ensure that actors strive towards the same goals, but it also recognizes their autonomy and the need for such.

One of the The current

Convergence is posited as the result of decision-making processes that consider both policy guidance and the specific local needs; it is grounded on teachers’ abilities to assess and respond to specific teaching demands. This also means governance systems should aim towards making certain that goals are understood by all actors and that teachers have the tools and support to achieve them. These aims, in turn, require that policy instruments provide teachers with the adequate professional training, pre-service and in-service, and that governance structures allow and enable teachers to establish their own goals and make decisions for their specific contexts. Goals, are particular to the actors, even as they are aimed in the direction of the general curricular goals –, and therefore they are realistic, achievable, and, most importantly, pertinent and relevant to the context. And as teachers establish goals of their own, they are more likely to appropriate them and, consequently, when well prepared, make better decisions to achieve them, both instructional decisions as well as for their professional development.

It is through these reflexive and interactive processes in which teachers, as professionals, engage with what they do, how and why they do it as well as with the systems’ learning goals that they can offer better OTL and move towards achieving system goals. The analysis of the
differences in OTL and teacher characteristics and the similarities in the use of policy
instruments between low and high performers support this idea; it is not adherence to curricular
prescriptions that leads to higher achievement, but professional decisions.

Particularly for low performers, often developing economies, achieving such change in
teachers’ role posits stronger challenges. Lacking many of the conditions that are necessary for
teachers to develop a better practice, determining policies with this end requires a careful review
and consideration of the current elements that define teacher practice, including culture and local
epistemologies. Autonomy, for example, cannot be established as a policy with the expectation
that teachers will exert such adequately; autonomy is developed on the bases of stronger
technical knowledge and capabilities, as well as adequate support, and only possible in
institutional and organizational structures and cultures that allow, encourage and orient it. In
other words, policy reform should be comprehensive and focus on gradual change.

6.3. Implications for establishing a high achieving curriculum

Moreover, this study is relevant to the current international discussion on curricular
standards – learning goals for specific content areas – and the idea that highly challenging
curricular or teaching standards ensure high achievement. Specifically in the U.S., the
establishment of national common standards (Common Core State Standards in English language
and mathematics) was expected to achieve higher learning across all schools under the
assumption that they would ensure students met these standards. However, the evidence does not
support this claim.

In the comparison of the intended curriculum across low and high performers, some
differences were found: more complex topics were included in the high performers’ curricula.
from earlier grades. However, important similarities were also identified. Overall, differences across groups of countries’ intended curriculum were not as pronounced as those in the enacted curriculum. That is, there are more commonalities in terms of the mathematics curricular intentions for the eighth grade between the two groups than teachers’ actual instruction suggests.

This finding reflects the convergence of mathematics curricular policy, as previous studies have also indicated (see Schmidt et al. 2001, Benavot 2012); it is also consistent with the discussion of the influence that global discourses and the broader social and cultural order, from a neoinstitutionalist perspective, exert on curricular policy (as well as other policy areas). According to this view, that the enacted curriculum does not show this same level of convergence across education systems is due to the slower rate at which teachers are adjusting to institutional directives.

That said, the variation seen in the OTL elements that define curricular policies across countries, particularly high performers, as well as the low correspondence between national directives and teachers’ instructional decisions, does not support the claim that a specific mathematics curriculum exists that will result in higher learning for students, that is, a “world-class” curriculum. High performers do not show a common pattern that differs from low performers’ intended curriculum.

Finally, there is no doubt that teachers play a prominent role in defining the curriculum; they interpret and adapt curricular standards to a local reality and the needs of their students, parting from their own knowledge and experience. Hence, it is argued that rather than strict alignment, it is the combination of teachers seeking to correspond with intentions and using their professional judgment to adapt the curriculum that leads to better learning. From the viewpoint of organizational theory, this combination of responsiveness and autonomy, shaped by beliefs,
experience, knowledge and the context, explains teachers’ actions and the variation in instructional practices, and consequently, a part of learning outcomes (Weick 1976; Orton and Weick 1990). Thus, a more interesting question would relate to how to enable teachers to better respond to students’ needs and adapt their resources for more meaningful instructional practices, particularly in low performing or developing countries.

6.4. Teacher and system factors and the enacted curriculum

The comparison made in this study of the policies that seek to direct the enactment of the curriculum in low and high performers – classified as such according to the TIMSS results – confirmed that, as hypothesized, curricular governance systems in these two groups have more in common than their outcomes might suggest. No elements were identified across all high performers alone, while differences were found within each group. Higher teacher preparation requirements, national curricular standards, teacher evaluation, and student assessments are some of the policies shared across most of the countries studied. The existence and influence of a global educational policy field which not only redefines education quality but also establishes the policies that lead to such quality (Lingard and Rawolle 2010; Meyer and Benavot 2013) are evident in the convergence of governance systems across continents.

Influenced by this global educational policy sphere, the adoption of world-class policies responds to the idea that they will produce the outcomes that are related to them in other contexts. An underlying assumption of this argument is that the policies will be executed as they have been in these other systems and according to their design. However, as this review of policies shows, despite the homogenization of education systems’, outcomes widely differ. Given findings of this study and consistent with other studies, differences are to a large extent
explained by the variation in implementation process; as the literature states, policies are redefined in their implementation according to the distinct national and institutional cultures and contexts in which they are immersed (Valverde 2004; Vavrus and Bartlett 2012; Watson 2009). But in addition to the national and institutional cultures, policies are also defined by the actors’ own experiences, knowledge and beliefs. The discussion of the results of the analysis of the relationship between system elements and individual teacher factors, on one side, and OTL, on the other, expands on the possible influences that define policies at the implementation level, focusing on the case of curricular policy and teachers as enactors of such.

Influences on teachers’ enactment of the curriculum

In relation to curricular policy, given the wide gap between intentions and enactment, found in both low and high performers, clearly teachers’ instructional decisions were influenced by factors other than the prescribed curriculum. This second part of this study explored this gap and its relationship to two kinds of factors: policies that define governance systems and teachers’ background and characteristics. The analyses sought to explore whether the association of these factors, common across governance systems, with teachers’ enactment of the curriculum differs across contexts. The specific factors explored were: teacher collaboration preparation, teachers’ use of textbooks, evaluation of teacher practice, teachers’ education and experience, teachers’ participation in professional development activities, and teachers’ perceived preparedness to teach. Continuing with the classification used to explore OTL, these associations were studied comparing countries that fare well in international student assessments and those that do poorly. Finally, in studying the possible association of factors on teachers defining of OTL, teachers are assumed as decision makers and enactors of the mathematics curriculum.
It was hypothesized that the association between different kinds of factors and the OTL teachers provided students with would differ between low and high performers, and that some patterns would emerge from each group. That is, the possible influence that factors, such as teachers’ preparation or the type of teacher evaluation, have on their enactment of the curriculum would not be the same across these two groups.

The results of the bivariate analyses between factors and OTL showed some significant relationships, supporting, in part, the thesis stated above. Some of the factors were significantly associated to elements of OTL – correspondence between intentions and enactment, more demanding performance expectations and IT – and these associations differed significantly between low and high performers. In some cases, the association with OTL was significant for only one group of countries, while not for the other; in others the association was positive for one group, while negative for the other. Although the size of the effects was small in all cases, these findings suggest that, first, the decisions teachers make regarding the mathematics curriculum they teach are influenced by most of these factors; second, they imply that the influence that each policy or factor in the education system exerts, in extent or nature, depends on the interaction of these factors with specific contexts and therefore differs across two groups and across countries and territories. It is proposed that as these associations interact and effects build on one another, differences in how teachers enact the mathematics curriculum also widen, and, in turn, so do the outcomes of what appear to be similar governance systems across the two groups.

As an example, teacher collaboration, which according to the literature translates into better learning outcomes when it originates in the school and develops as part of its culture as opposed to a top-down mandate (Hargreaves 1992; Hargreaves 2009; Hargreaves 2013), seems to bring teachers to different instructional decisions: in low performers collaboration was
associated with better correspondence between intentions and enactment, while in high performers, it was associated with lower correspondence. It then can be argued that teacher collaboration has developed in distinct ways in different contexts, depending on teachers’ knowledge, experience, beliefs, and other school and system factors, such as the mechanisms that exist to guide and support it. Accordingly, as a policy, collaboration among teachers would achieve limited results in a context where teacher characteristics and the organizational structure do not favor the kind of interaction that enables teachers to make decisions and take actions that translate into better learning outcomes.

Of particular importance in establishing adequate curriculum governance systems, is the issue of teacher accountability, which is at the center of current teacher policy trends. The different kinds of mechanisms established with a focus on making teachers accountable have different effects (UNESCO 2017). According to findings of this study, teacher supervision, for example, appears to have distinct effects in differing contexts in relation to convergence, and such is also the case for supervision by school staff, including the principal. Clearly, the nature of the supervision generates different responses, but it also develops in various ways depending on the organizational and institutional structures, teachers’ preparation and professional autonomy, and the role and capabilities of school leaders. Thus, the selection of teacher accountability policies should consider the kind of change sought, the current conditions of the system in which policies will be implemented, as well as to the gradual changes that will be necessary for such policies to take place as intended.
Effectiveness of borrowed policies

This analysis of teachers’ enactment of curricular policy across countries that have much in common in terms of curricular prescriptions as well as in their curricular governance systems, but widely different outcomes offers further evidence opposing the idea of world-class policies. Taken from contexts with high achievement, adopting “world-class” policies assuming that they will bring similar results ignores the complexity of systems and the relevance of the actors responsible for implementing such policies in its success. Moreover, it limits the possibilities that policy-making responds to the local demands and includes the participation and input of local stakeholders, increasing with that the policy’s feasibility; overall, it limits the chances of developing better and more pertinent policies.

However, policy-borrowing, as countries seek to find answers to the long-standing problems of their education systems, is inevitable, as it is desirable to learn from other experiences. After all, it is also the demands for improvement that come from different actors within countries, especially low performing ones, that drives education leaders to consider and even welcome “solutions” promoted by global education regimes (Valverde 2014). Thus, for policymakers, these findings imply that adopting a policy that has shown to have positive effects in other places requires considering the elements that allowed it to be successful in its original context, as well as the characteristics of the education system in which the policy would be implemented. It requires assessing the conditions for its implementation, taking into account existing policies, organizational structures and cultures, institutions’ capacities as well as the general political, social and economic context in which these are embedded. It also demands building consensus and diminishing resistance to policy change by bringing the participation of actors in the policy defining process.
As the previous studies have pointed out in the case of curricular policy, teachers interpret and enact the curriculum acting on their knowledge and experience (Spillane 2000; Spillane et al. 2002); thus, for policy makers, anticipating these interpretations, possible resistance, and the capacity to perform, by analyzing and considering the characteristics of the education system, including teachers’ knowledge and the experiences provided to them, would help establish possible scenarios for the implementation of the policy; this would contribute to making decisions for better designed policies and adequate implementation processes.

Moreover, it is also evident that even when, broadly, the contexts could be considered similar, some elements, including cultural and historical ones, are likely to differ. Thus, in implementing policies that have seemed to work in similar contexts, it is important that steps are planned to ensure that the ideal conditions for implementation exist or will develop. This means that adopting a policy or creating a program with a specific aim should entail a broader vision of how to bring about the change desired.

More generally, the findings of this study provide empirical evidence to further question the worldwide acceptance and promotion of curriculum policies that, given their existence in education systems that even for the first time place high on the list in international assessments, such as TIMSS, are recognized as undoubted solutions or best practices, required to improve education outcomes. This focus on high performers as producers of policy answers has made most actors in policy regimes, including policymakers, oblivious to the reality of low performers and to the fact that, as this study has shown, curriculum policies in high performers are, and in some cases have for long been, part of low performers’ governance systems. Thus, these worldwide best policy solutions grounded on little analysis and strengthened by the need to find
fast answers, are taking countries into continuous cycles of policy change, accompanied by high expectations that are unmet.

6.5. Future research

The findings in this study have revealed important questions that should be the subject of future analysis. The first and perhaps one of the more interesting questions relates to the extent to which teachers in low performers report using high demanding performance expectations in their mathematics class. Qualitative research that explores teaching as well as teachers’ interpretations, assumptions and approaches to teaching challenging mathematics is necessary to understand these differences and, more broadly, how teachers define curricular policy. The limits of self-reported data, the basis of this study, are well known, and therefore, further analysis of teachers’ instruction using other methods, such as teacher logs, classroom artifacts, and classroom observation, is necessary to obtain better measures and analyze these and other explanations for the reported use of HDPE in low performing countries. The validity and the extent to which survey methods can depict teaching processes across different contexts, especially those that are considered more cognitively demanding, should also be studied further.

Another issue for empirical research is the relationship between the use of low and highly challenging performance expectations or cognitive processes in mathematics instruction. The answers to these issues are relevant in high as well as in low performing contexts.

Moreover, correspondence between curricular intentions and teachers’ enactment of the curriculum should be explored further, not as an aim of curricular governance systems, but to understand how policies support teachers’ instruction, especially given the importance of teachers’ role to learning. Research should focus on the kinds of interactions between these two
levels of the curriculum that foster better mathematics teaching processes. The questions should address how the curriculum governance system can better support teachers’ autonomy and more adequate, efficient and effective decision making.
References


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Mullis, Ina V.S., Michael O. Martin, Pierre Foy, and Alka Arora. 2012. “TIMSS 2011 International Results in Mathematics.” Published by TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College, MA, USA and International Association for the Evaluation of Educational Achievement (IEA) IEA Secretariat Amsterdam, the Netherlands.


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Appendix
Variables, source and items

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source (TIMSS 2011)</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content topics</td>
<td>Teacher questionnaire</td>
<td><strong>Enacted curriculum</strong></td>
</tr>
</tbody>
</table>

ET1. The following list includes the main topics addressed by the TIMSS mathematics test. Choose the response that best describes when the students in this class have been taught each topic. If a topic was in the curriculum before the <eighth grade>, please choose “Mostly taught before this year.” If a topic was taught half this year but not yet completed, please choose “Mostly taught this year.” If a topic is not in the curriculum, please choose “Not yet taught or just introduced.”

Check one circle for each line.
 Mostly taught before this year
 Mostly taught this year
 Not yet taught or just introduced

**A. Number**
- a) Computing, estimating, or approximating with whole numbers
- b) Concepts of fractions and computing with fractions
- c) Concepts of decimals and computing with decimals
- d) Representing, comparing, ordering, and computing with integers
- e) Problem solving involving percents and proportions

**B. Algebra**
- a) Numeric, algebraic, and geometric patterns or sequences (extension, missing terms, generalization of patterns)
- b) Simplifying and evaluating algebraic expressions
- c) Simple linear equations and inequalities
- d) Simultaneous (two variables) equations
- e) Representation of functions as ordered pairs, tables, graphs, words, or equations

**C. Geometry**
- a) Geometric properties of angles and geometric shapes (triangles, quadrilaterals, and other common polygons)
- b) Congruent figures and similar triangles
- c) Relationship between three-dimensional shapes and their two-dimensional representations
- d) Using appropriate measurement formulas for perimeters, circumferences, areas, surface areas, and volumes
- e) Points on the Cartesian plane
- f) Translation, reflection, and rotation
<table>
<thead>
<tr>
<th>Performance expectations</th>
<th>Teacher questionnaire</th>
<th>ET2. In teaching mathematics to this class, how often do you usually ask students to do the following? (every or almost every lesson; about half the lessons; some lessons; or never)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>b) Memorize rules, procedures, and facts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>f) Apply facts, concepts, and procedures to solve routine problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>g) Explain their answers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>h) Relate what they are learning in mathematics to their daily lives</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i) Decide on their own procedures for solving complex problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>j) Work on problems for which there is no immediately obvious method of solution</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructional strategies</th>
<th>Teacher questionnaire</th>
<th>ET3. In teaching mathematics to this class, how often do you usually ask students to do the following? (every or almost every lesson; about half the lessons; some lessons; or never)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a) Listen to me explain how to solve problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Work problems (individually or with peers) with my guidance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>e) Work problems (individually or with peers) while I am occupied by other tasks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructional time</th>
<th>Teacher questionnaire</th>
<th>ET4. How often do you do the following in teaching this class? (every or almost every lesson; about half the lessons; some lessons; or never)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a) Summarize what students should have learned from the lesson</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Relate the lesson to students’ daily lives</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Use questioning to elicit reasons and explanations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructional time</th>
<th>Teacher questionnaire</th>
<th>ET5. In a typical week, how much time do you spend teaching mathematics to the students in this class?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>___________ hours and ___________ minutes per week</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Write in the hours and minutes.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructional time</th>
<th>Teacher questionnaire</th>
<th>ET9. By the end of this school year, approximately what percentage of teaching time for mathematics will you have spent during this school year on each of the following mathematics content areas for the students in this class?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a) Number (e.g., whole numbers, fractions, decimals, ratio, proportion and percent) %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Algebra (e.g., patterns, equations, formulas and relationships) %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Geometry (e.g., lines and angles, shapes, congruence and similarity, spatial relationships, symmetry and transformations) %</td>
</tr>
</tbody>
</table>
d) Data and chance (e.g., reading, organizing and representing data, data interpretation and chance) ------ ___%  
e) Other ------------------------------------------ ___%  

---

**School questionnaire**

**ES6.** How many days per year is your school open for instruction?  
_________ days  
Write in the number.

**ES7.** What is the total instructional time, excluding breaks, in a typical day?  
_________ hours and __________ minutes  
Write in the number of hours and minutes.

**ES8.** In one calendar week, how many days is the school open for instruction?  
Check one circle only.  
6 days ---  
5 1/2 days ---  
5 days ---  
4 1/2 days ---  
4 days ---  
Other ---  

---

**Intended curriculum**

**Content topics**

**Curriculum questionnaire**

**IC10.** (i) According to the national mathematics curriculum, what proportion of grade 8 students should have been taught each of the following topics or skills by the end of grade 8?  

*Be sure to include curriculum expectations for all grades up to and including grade 8. Grades represent years of formal schooling. For example, if “Year 9” in your country corresponds to the eighth year of formal schooling, please choose grade 8.*

Across grades from preprimary through upper secondary education, at what grade(s) are the topics primarily intended to be taught?

*If there are not any specifications to this detail, please indicate national expectations to the best of your ability. If part of a topic does not apply (e.g., estimation in part A topic (a)), please explain in the comment field. Refers to the national curriculum that covers mathematics instruction at the eighth grade of formal schooling for the majority of students. If you do not have a national curriculum, please summarize for your state or provincial curricula.*

**A. Number**

a) Computing, estimating, or approximating with whole numbers---------  
b) Concepts of fractions and computing with fractions  
c) Concepts of decimals and computing with decimals---------  
d) Representing, comparing, ordering, and computing with integers---------  
e) Problem solving involving percents and proportions---  

**B. Algebra**

a) Numeric, algebraic, and geometric patterns or sequences (extension, missing terms, generalization of patterns)- ---------  
b) Simplifying and evaluating algebraic expressions---------  
c) Simple linear equations and inequalities---------  
d) Simultaneous (two variables) equations---------
C. Geometry
a) Geometric properties of angles and geometric shapes (triangles, quadrilaterals, and other common polygons)------
b) Congruent figures and similar triangles---------------
c) Relationship between three–dimensional shapes and their two-dimensional representations-----
d) Using appropriate measurement formulas for perimeters, circumferences, areas, surface areas, and volumes------
e) Points on the Cartesian plane
f) Translation, reflection, and rotation

D. Data and Chance
a) Reading and displaying data using tables, pictographs, bar graphs, pie charts and line graphs---
b) Interpreting data sets (e.g., draw conclusions, make predictions, and estimate values between and beyond given data points) ------------
c) Judging, predicting, and determining the chances of possible outcomes

<table>
<thead>
<tr>
<th>Performance expectations</th>
<th>Curriculum questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IC11. How much emphasis does the national mathematics curriculum place on the following?</strong> (None; very little; some; a lot)</td>
<td></td>
</tr>
<tr>
<td>0 = none</td>
<td></td>
</tr>
<tr>
<td>1 = very little</td>
<td></td>
</tr>
<tr>
<td>2 = some</td>
<td></td>
</tr>
<tr>
<td>3 = a lot</td>
<td></td>
</tr>
</tbody>
</table>

a) Mastering basic skills and procedures
b) Applying mathematics in real-life contexts
c) Reasoning mathematically

<table>
<thead>
<tr>
<th>Instructional time</th>
<th>Curriculum questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IC12. Does your country have a nationally mandated number of school days per year?</strong> (Yes/no)</td>
<td></td>
</tr>
<tr>
<td>Please describe:</td>
<td></td>
</tr>
</tbody>
</table>

**IC13. Does the curriculum prescribe the percentage of total instructional time to be devoted to mathematics instruction at the eighth grade of formal schooling?**

*Refers to the national curriculum that covers mathematics instruction at the eighth grade of formal schooling for the majority of students. If you do not have a national curriculum, please summarize for your state or provincial curricula.*

Yes---
No---
*If Yes,…*
Please specify the percentage:

---

**Policy instruments and teacher factors**

<table>
<thead>
<tr>
<th>Teacher education</th>
<th>Teacher questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FT14. During your &lt;post-secondary&gt; education, what was your major or main area(s) of study?</strong> (yes/no)</td>
<td></td>
</tr>
<tr>
<td>Check one circle (yes/no) for each line:</td>
<td></td>
</tr>
<tr>
<td>a) Mathematics</td>
<td></td>
</tr>
<tr>
<td><strong>Evaluation of teacher practice</strong></td>
<td><strong>School questionnaire</strong></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td><strong>FS13. In your school, are any of the following used to evaluate the practice of &lt;eighth-grade&gt; mathematics teachers?</strong></td>
<td></td>
</tr>
<tr>
<td>a) Observations by the principal or senior staff</td>
<td>b) Observations by inspectors or other persons external to the school</td>
</tr>
<tr>
<td>c) Student achievement</td>
<td>d) Teacher peer review</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Teacher professional development</strong></th>
<th><strong>Teacher questionnaire</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FT16. In the past two years, have you participated in professional development in any of the following? (yes/no)</strong></td>
<td></td>
</tr>
<tr>
<td>a) Mathematics content</td>
<td>b) Mathematics pedagogy/instruction</td>
</tr>
<tr>
<td>c) Mathematics curriculum</td>
<td>d) Integrating information technology into mathematics</td>
</tr>
<tr>
<td>e) Improving students’ critical thinking or problem solving skills</td>
<td>f) Mathematics assessment</td>
</tr>
<tr>
<td>g) Addressing individual students’ needs</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Textbook use</strong></th>
<th><strong>Teacher questionnaire</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FT17. When you teach mathematics to this class, how do you use the following resources? (basic instruction; supplement; not used)</strong></td>
<td></td>
</tr>
<tr>
<td>a) Textbooks</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Teacher collaboration</strong></th>
<th><strong>Teacher questionnaire</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FT18. How often do you have the following types of interactions with other teachers?</strong> (never or almost never; 2 or 3 times a month; 1-3 times per week; daily or almost daily)</td>
<td></td>
</tr>
<tr>
<td>a) Discuss how to teach a particular topic</td>
<td>b) Collaborate in planning and preparing instructional materials</td>
</tr>
<tr>
<td>c) Share what I have learned about my teaching experiences</td>
<td>d) Visit another classroom to learn more about teaching</td>
</tr>
<tr>
<td>e) Work together to try out new ideas</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Teacher experience</strong></th>
<th><strong>Teacher questionnaire</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FT19. By the end of this school year, how many years will you have been teaching altogether?</strong></td>
<td></td>
</tr>
<tr>
<td>Please round to the nearest whole number.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Teachers perception of teachers understanding of the school’s curricular goals</strong></th>
<th><strong>Teacher questionnaire</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FT20. How would you characterize each of the following within your school?</strong> (5=very high; 4=high; 3=medium; 2=low; 1=very low)</td>
<td></td>
</tr>
<tr>
<td>b) Teachers’ understanding of the school’s curricular goals.</td>
<td></td>
</tr>
<tr>
<td>Teachers’ own perceived preparedness to teach</td>
<td>Teacher questionnaire</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>FT21. How well prepared do you feel you are to teach the following mathematics topics?</td>
<td></td>
</tr>
<tr>
<td>If a topic is not in the &lt;eighth-grade&gt; curriculum or you are not responsible for teaching this topic, please choose “Not applicable.” (1 = Not applicable; 2 = very well prepared; 3 = somewhat prepared; 4 = not well prepared)</td>
<td></td>
</tr>
<tr>
<td><strong>A. Number</strong></td>
<td></td>
</tr>
<tr>
<td>a) Computing, estimating, or approximating with whole numbers</td>
<td></td>
</tr>
<tr>
<td>b) Concepts of fractions and computing with fractions</td>
<td></td>
</tr>
<tr>
<td>c) Concepts of decimals and computing with decimals</td>
<td></td>
</tr>
<tr>
<td>d) Representing, comparing, ordering, and computing with integers</td>
<td></td>
</tr>
<tr>
<td>e) Problem solving involving percents and proportions</td>
<td></td>
</tr>
<tr>
<td><strong>B. Algebra</strong></td>
<td></td>
</tr>
<tr>
<td>a) Numeric, algebraic, and geometric patterns or sequences (extension, missing terms, generalization of patterns)</td>
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<tr>
<td>b) Simplifying and evaluating algebraic expressions</td>
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<tr>
<td>c) Simple linear equations and inequalities</td>
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<tr>
<td>d) Simultaneous (two variables) equations</td>
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<tr>
<td>e) Representation of functions as ordered pairs, tables, graphs, words, or equations</td>
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<tr>
<td><strong>C. Geometry</strong></td>
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<tr>
<td>a) Geometric properties of angles and geometric shapes (triangles, quadrilaterals, and other common polygons)</td>
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<tr>
<td>b) Congruent figures and similar triangles</td>
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<tr>
<td>c) Relationship between three-dimensional shapes and their two-dimensional representations</td>
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<tr>
<td>d) Using appropriate measurement formulas for perimeters, circumferences, areas, surface areas, and volumes</td>
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<tr>
<td>e) Points on the Cartesian plane</td>
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<tr>
<td>f) Translation, reflection, and rotation</td>
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<tr>
<td><strong>D. Data and Chance</strong></td>
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<tr>
<td>a) Reading and displaying data using tables, pictographs, bar graphs, pie charts, and line graphs</td>
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<tr>
<td>b) Interpreting data sets (e.g., draw conclusions, make predictions, and estimate values between and beyond given data points)</td>
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<tr>
<td>c) Judging, predicting, and determining the chances of possible outcomes</td>
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</table>
| Teachers’ perception of school’s teachers’ expectations for student achievement | Teacher questionnaire | **FT22. How would you characterize each of the following within your school?** (5 = very high; 4 = high; 3 = medium; 2 = low; 1 = very low)

d) Teachers’ expectations for student achievement |

*Source: Items used from TIMSS 2011 study*